THE GROWTH OF EXCLUSION OF VARIABLES DURING ADOLESCENCE

THESIS

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CERTIFICATE

I am pleased to certify that Miss Padmini Kannayath Sukumaran has worked on the problem "The Growth of Exclusion of Variables During Adolescence – A Study". This thesis is a record of bonafide research carried out by her for the award of Ph.D. degree under my guidance and supervision and no part of the work has been submitted for any degree earlier.

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CHAPTER I

SOME SCIENTIFIC IDEAS

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Introduction

Science has always been a force of progress in the history of civilization. The term 'science' though, is etymologically synonymous with knowledge, all knowledge is not science. The scientific knowledge man has acquired over the centuries has given him immense power. Achievement in modern science has ushered an era of exploration of the cosmos and development of modern biology, biophysics, micro-biology and biochemistry. This is an age of 'space travel' as well as 'nuclear energy'. To quote Prof. Irwin Lesnick :

> The world we live in is a marvel of man's mastery over his environment. Through the explosive development of the Natural Sciences, we now predict, control and understand phenomena to an extent never fully envisioned, throughout the millions of years of human development prior to the current century. The scientific revolution has maximised opportunities for human happiness, and through its technical arms is [illegible] material wealth and long and healthy [illegible] knowledge and the process by which it is obtained, promise a spiritual fulfilment unavailable from the dry bones of fatalism and mysticism.

The impact of science and technology is more in a developed country than in a developing or under developed country. Unless the fruits of science are used or applied by a country, it can make little progress. To meet the demands of a science and technology oriented society, the focus of education should be on the development of the ability to think critically and imaginatively. As Victor H. Noll put it, "the practical objective is not to make every one 100 per cent open minded, or 100 per cent accurate or 100 per cent critical but to make everyone more open minded, more accurate and more critical than he now is". In the last decade, the teaching of science has undergone some important changes enabling the children leave school today with a better understanding of science than the children a scant ten years ago. They are better equipped to cope with the present prevailing social conditions which is very different from those of yester years.

Importance of Thinking for Problem Solving

The impact of science and technology on the economic and social life of a nation has been profound. Life has become challenging and complex because of the double-edged products of science, that is, happiness and disaster. Besides atoms equally used for peace and war, the problems that face man today are many and varied. The rapidly changing world exposes him to new social situations, new disease, new professions and new adjustment problems due to changing attitudes and values of life. Traditional methods fail to solve the complex problems of the modern age. Thus the need

for man to develop the capacity to cope with new situations has arisen. The ability to recognize and solve practical problems as well as to tackle intellectual ones have become the major goal of education today. Over the centuries, the philosophers and, later, the psychologists tried to study and explain the human behaviour and human mind. Human mind has fascinated man due to its unique capacity to think. The thinking capacity of the most intelligent animal is found to be nowhere near to his. The methods employed to study the mind, by the philosophers and earlier psychologists being vague, they succeeded only partially and failed to give a total picture of the working of the human mind. Their endeavour, however, indicated that thinking is a very complicated process, than the common sense acquaintance with it might lead one to suppose. Educationists and psychologists today have taken a keen interest in studying and understanding the various thinking processes underlying the working of the mind, because the need for it is most urgent today than ever before, because man is confronted with complex problems at present which can be solved only by abstract, logical thinking. Successful problem solving leads to successful living. The history of civilization itself is a document of how man solved the various problems he encountered.

Thinking

In a general sense, the term 'thinking' refers to 'Guessing, imagining, opening, remembering, reflecting and searching for conclusion' etc. The philosophers studied 'thinking' in terms of its product and have thus developed

their laws of thought : law of identity, law of contradiction and law of excluded middle etc. In a restricted psychological sense, it may refer to 'percepts, images, vocal sounds, feelings and ideas' etc. Occasionally, it has also been used in terms of 'mind, consciousness and judgement'. At present, the term 'thinking' is identified with problem solving.

Nineteen types of thinking were identified by Symonds, such as learning, reasoning, stating relationships etc. Thinking according to Burt and his students consisted of 'a heirarchy of thinking abilities comprising of relation, association, perception and sensation etc. According to John Dewey, the need for thinking arises when there is an obstacle in the way of goal directed activity. With special reference to school subjects, Peel's identification of four types of thinking, viz., Thematic explanatory, productive and integrative, is of interest :

Thematic Thinking : Thinking is called 'Thematic' when the thinking of the pupil is not supposed to solve any practical problem or meet any practical criterion. In this case, he can speculate freely. Such thinking is consistent with the theme of the essay, painting or piece of music. Since the thinking is described in terms of content or product, it is called Thematic thinking.

Explanatory Thinking : This kind of thinking is more controlled than the thematic thinking. The direction of thought has to conform to a particular criterion of explaining events. All school subjects require explanatory thinking i.e. describing

and explaining events and things. Explanatory thought provides the 'potentiality or jumping off point for real control over and manipulation of environment'. The control of the association by practical criteria, the testing of hypotheses against the facts, the acceptance of some event or theory as being reasonably probable and the formation of language that deals with concepts and classes of objects are some of its distinguishing characteristics.

Productive Thinking : When the attack on a problem is taken beyond the stage of explanation and used to modify the situation so that the original problem is altered, the subject is, thinking in a productive way. Like explanatory thinking, it enters into every school subject. It often enters into practical science experiments as well when the pupil is asked to 'arrange a set of pulleys or levers to obtain a given mechanical advantage or to arrange a concave mirror and small light so that he can see down a person's throat'. The main features of productive thinking are that it starts from explanatory thought but is different in that, it contains an element of forward thinking; the problem situation is materially changed in order to achieve the solution; in the light of established explanation, the problem is restated to solve them effectively; it appears everytime a new problem situation is met and the situations that calls for this. Lastly, this type of thinking may be material, social or personal.

Integrative Thinking : This type of thinking concerns with the fundamentals like time, space, matter, causality, beauty, goodness, truth, life etc. The child and adolescent ask questions and theories about these ultimates. The thinking is hypothetico-observational in the first place, in that, it proceeds by observation and experimentation. The thinker knows to some extent what he is looking for. Secondly, integrative thinking is analytico-disjunctive. Although the experimenter knows what he is looking for, this knowledge may arise from alternative hypotheses, his capacity to choose the most appropriate hypotheses and eliminate the others. Thirdly, the integrative thinker proceeds from a challenge to common sense. And his new hypotheses is at once more synthesising and more sensitive. At this stage, the thinking is often deductive. It is the highest form of thinking which appears among highly creative individuals. The first three types of thinking are present in most of the school children and the last among very few.

The Geneva School

Another great recent psychologist, the late Prof. Jean Piaget (1896-1980), whose contributions for the development of cognition is immense, is yet to be absorbed by the educationists and curriculum framers. He gave the world the famous 'Piagetian Theory' epitomised in the Geneva school. He gave four stages in the development of intelligence as follows :

1. Sensory Motor Stage (Birth to 2 years)

This is the first stage of Piaget's mental development beginning with the infant showing the capacity for a few reflexes endowed at birth and ending when the child acquires the rudiments of language and symbolic ways of representing the world. The salient feature of this stage is the total lack of internalization of thought processes. Their 'action is without representation'. The child however learns by interacting with the environment with his senses and muscles. Piaget has further divided this stage into six sub stages : I. (birth - 1 month) - Uses the reflexes provided at birth. II. (1 month - 4 months) shows acquired adaptations and primary circular reactions. III. (4 - 8 months) shows secondary circular reactions, object permanence and construction of space and incorporates new objects into existing schemata. IV. (8 - 12 months) there is coordination of secondary schemata and their application to new situation. V. (12 - 18 months) teritiary circular reactions, object permanence, space, time and causality is seen here. VI. (18 - 24 months). At the last substage, the child begins to make internal, symbolic representation of the sensory motor problems and invents new 'means-end relation'. Object permanence, space, time and causality are again found here.

The sensory motor stage is a 'time of transition from the cognitive contents (imitation, circular reactions, object permanence, causality and space) that are entirely overt to

cognitive contents that are 'internalized or mental' (Brainerd, 1978).

II. Pre-Operational Stage (2 - 7 years)

This stage of mental development is also called the 'representational stage'. It is in this stage that the development of language begins. The verbal labels are related to immediate objects and events or wishes but later, to even those that are not present but immediate as the development of memory is limited. The four cognitive contents of the pre-operational stage are : egocentrism, causality concepts, language and identity. However, according to Piaget, the pre-operational child fails to conserve mass, weight, length, volume etc. and lacks reversibility in his schemes. He also fails to integrate (relate) different bits of information or events into one whole. Piaget has split this stage into two parts : I (2 - 4 years), the thinking here is said to be transductive and in II (4 - 7 years), the thinking is intuitive. During the pre-operational stage, the child acquires the capacity to integrate different bits of information into one meaningful whole. However, the internalizations of actions do not take place to the stage that the child can perform or use a system of operations. The child's thinking is mostly dominated by perception.

III. Concrete Operational Stage (7 - 11 years)

This third stage of cognitive development is significant because the thinking here comes closer to mature, adult thought. Here true operations are present but are confined only to

concrete situations. That is, they are not abstract. The thought processes are no longer intuitive as in the previous stage. Here they begin to reason and acquire the conservation concepts. The two principal types of concrete operations are: (a) 'logico-arithmetic operations (process discrete data) and (b) spatial operation (process continuous data)'. The four cognitive contents of this stage are 'conservation, relations, classification and number'.

IV. Formal Operational Stage (11 to 15 years)

This is the most crucial stage as it develops during adolescence, described as a period of trouble and turmoil, emotionally unstable, constant and unrelieved conflict. Piaget contradicts this traditional view and claims it to be the most productive period of life. According to him, the thought process acquires the refineness of adult thought. This stage is markedly different from the previous stage by dealing with the "possible versus the real". Brainerd (1978) aptly describes this stage as (a) hypothetico-deductive, (b) scientific and (c) reflective - abstractive. And, Flavell (1963) describes it as "A generalized orientation, sometimes explicit and sometimes implicit towards problem solving: an orientation towards organizing data (combinatorial analysis), toward isolation and control of variables, towards the hypothetical and towards logical justification and proof". The key mental structure of the formal operations is a special type of mathematical group called the INRC structure. This INRC group is a set of four

reversibility operations in which each operation has special properties (I = identity operation, N = inverse operation, R = reciprocal operation, C = correlations operation). With the acquisition of formal thought, Piaget believes that intelligence has reached the ultimate equilibrium and no further qualitative structural changes will occur.

Recently, he had hinted at the possibility of a fifth stage called the "problem finding stage" (Arons, 1975) between 15-20 years, considering factors like aptitude variations and commitment to individual careers.

Other researchers whose works have contributed and enriched the problem-solving territory in recent years are those of Ausubel, Bartlett, Beard, Bruner, Flavell, Gagne, Guilford, Hennefurth, Hearnshaw, Humphrey, Inhelder, Karplus, Lovell, Lunzer, Richards, Skinner, Suchman, Vernon and Wallas. This literature clearly reveals that children learn with or without formal education, from their immediate environment. Thinking processes of children are markedly different from those of adults and are intelligible and predictable.

So any educational system is said to be worthy of its existence only when the education fosters in the child leaving school with the capacity to tackle the various problems and solve them successfully. The purpose of schooling should not be confined to training them to do only specific jobs. Children trained to solve school problems, will be of little value to them for they are likely to face problems in life and society

which are entirely different from those they encountered at school. Thus, the school should emphasise not on the solution of some specific problems but should imbibe in the students with the processes or ways to deal with a wide variety of problems they are yet to face. If only, the educationists look into the quite rich literature of the recent years on cognitive development, especially that of Jean Piaget, who devoted his life to the formation of a theory of intellectual development, they can frame curriculum according to age and intellectual capacity of the children which in turn helps them to solve the problems more intelligibly and successfully.

Need of the Study

A clear picture of the schemes of thought, the adolescent pupils adopts to solve problem, is yet to be arrived at. In this context, it can be said that no study in this country as far as the knowledge of the investigator goes has attempted to develop even a single test instrument (using a series of diverse science problems) and psychometresize it with a view to investigate the adolescent scheme of thought 'Exclusion of Variables' intensively along with a large number of outside variables like personality factors, aptitude, intelligence and other schemes of thought (N = 33).

Aims and Objectives of the Study

1. To investigate adolescent thought through a short, reliable and valid test instrument, incorporating Piaget type tasks.

2. To determine the relationships between the scores on certain aspects of Exclusion of variables and some outside variables : Age, Sex, Intelligence, Personality characteristics and Aptitude.

3. To analyse the structure of Exclusion of variables, along with three other schemes of thought, mathematically and interpret it psychologically.

4. To determine the characteristics of successful and unsuccessful problem solvers on Piaget type tasks.

5. To point out the main educational implications based upon the findings of the study.

Statement of the Problem

It was finally decided to take up the following problem:

THE GROWTH OF EXCLUSION OF VARIABLES AMONG ADOLESCENTS

It is one of the most important variables which ought to develop during the fourth stage of mental development as pointed out by the Geneva school under the leadership of Prof. Jean Piaget. It informs that the individual minds of adolescent pupils become truly experimental during this stage. It is yet to be tested empirically how far do they really become so? With a view to understand the nature of this variable, it was considered as a bi-structural construct, namely, stating and testing hypotheses, through the medium of several problem inhering a continuous chain of reasoning, exhausting possibilities, proposing problems not easily self-answerable and

grasping the essence of the problem. As the scope of the study was highly limited and confined to the investigation of a single scheme of thought, it was decided to investigate at depth the above mentioned variable in relation to several outside variables, namely, Age, Intelligence, six Aptitudes (Abstract reasoning, Language usage, Mechanical reasoning, Numerical ability, Space relations and Verbal reasoning), fourteen personality traits (Reserved/outgoing, Concrete thinking/Abstract thinking, Emotionally less stable/Emotionally stable, Phlegmatic/Excitable, Obedient/Assertive, Serious/Heedless, Expedient/Conscientious, Shy/Adventurous, Tough-minded /Tender-minded, Zestful/Circumspect, Secure/Insecure, Group dependent/Self sufficient, Uncontrolled/Self-disciplined and Relaxed/Tense). The data so collected were subjected to the statistical analysis including the factor analytic technique.

About the Thesis

The present study has been described in eight chapters excluding the appendix.

The first chapter deals with the background to the study. It points out the various problems and issues in content in the present area of work. The second chapter deals with the survey of studies undertaken in this area by the various workers. While providing the general conclusions based upon the consolidated studies having varied aims and objectives, procedures and samples, tools and techniques, it also tells how this study is different from the other studies. The third chapter consists

of two sections A & B. Section A deals with the design of the study and Section B deals specifically with the development of the test instrument and the limitations of the instrument. The fourth chapter presents analysis of data on individual problems contained in the test instrument. The fifth chapter deals with the factorial structure of the problems and other tests ($N=30$). The sixth chapter deals with some statistical relationships not covered in the fourth chapter. Some interesting data not looked for, relevant to the hump effect, appeared which are described in the seventh chapter. The last chapter contains the summary of the present work, not excluding ofcourse, are the additional problems as well as educational implications arising out of this study.

CHAPTER II

A CRITICAL REVIEW OF ADOLESCENT THINKING
WITH
SPECIAL REFERENCE TO SELECTION OF VARIABLES

CHAPTER II

A CRITICAL REVIEW OF ADOLESCENT THINKING WITH SPECIAL REFERENCE TO EXCLUSION OF VARIABLES

Introduction

'Adolescence' is a period of interest to researchers because the development during this period transforms the child into a unique individual. He matures : physically, psychologically, socially and intellectually. Early research works reveal that more emphasis was given on the study of the affective and the social life of the adolescent. It is of late that, after the various intelligence tests revealed that the thinking ability of adolescents are markedly different from those of children, the researchers have taken special interest to study the 'intellectual development' or 'thinking ability and the processes involved in it' during adolescence. Ausuble (1954) found that intellectual growth in adolescence proceeds smoothly from earlier stages unlike the physiological, personality and social development where the development shows a sudden spurt during adolescence. In 1955, Thurstone identified six primary mental abilities of which space and reasoning factors were found to mature at the age of fourteen years, memory and number at sixteen, verbal comprehension and word fluency beyond sixteen. Bayley (1957) noticed I.Q. gains during the ages sixteen to

twenty one. Sontag and Kagan (1963) found during adolescence, independent behaviour, achievement motivation and efficient intellectual performance were interrelated. It was, however, Piaget (1954) who gave the most elaborate theory of cognitive development by his prodigious work. The development of cognition according to Piaget takes place in four stages : sensory motor, preoperational, concrete operational and formal operational. The last stage is of interest as it develops during adolescence and is the highest form of reasoning (thinking). Adolescence, in contrast to the trouble and turmoil view, is regarded by Piaget as the most exhilarating and productive time of life. Formal operational thinking develops during adolescence between the ages 11-15 years. The formal operational stage concerns 'possible versus the real'. The thinking at this stage is sophisticated in the sense it is highly logical and it involves: Hypothetico-deductive operations, Proportional logic and Combinatorial systems. The adolescents tend to attach the problems more systematically in anorganised manner to solve them. Though his theory was slow to be accepted, it now stands acclaimed all over the world, giving food for thought to researchers outside Geneva.

Some Related Studies

As one goes through the research literature, it is found that researches conducted outside Geneva still deals more with concrete operational stage than the formal stage of cognitive development. The formal operational thought in relation to factors like : cultural, social and personality traits of

adolescents are yet to be investigated by many to get a clear picture. With regard to the mathematical structure of adolescent thought, only very recently a handful of studies have appeared. The few studies that have direct bearing on the present study are described below.

Smoke (1961) investigated the role of hypotheses formation in the process of concept formation. He experimented with ten different concepts where each concept consisted of eight regular features and eight confusion features. He concluded that there is some form of grouping in concept formation and the hypotheses in concept formation are set up or tested for their validity. Besides, he found that though the subjects had acquired the concepts they had difficulty in verbalizing them.

Beard (1962) studied the effect of schooling on scientific reasoning and found that for 8 to 16 year olds, the level of logical thinking varied extensively between schools. Almost all subjects in one school failed to either treat the variables in the task independently or to conclude that only one variable was significant. In another school, nearly all subjects over age 10 were able to separate the variables. Yet in another, three subjects showed the usual pattern of increasing success with age. Previous classroom experience appeared to play an important part in the ability to control variables.

Vaidya (1964) using questionnaire approach (N = 60) as well as interview approach (N = 31), found adolescent boys of two schools in central London, solving science problems over a wide I.Q. range (on 11+ test). The study also revealed that

generally the adolescent pupils set-up hypotheses which they test against the given data.

Necks and Necks (1971) are the only investigators who found a sample of 15 year olds who all appeared to use the formal operations. However, they determined that a subject used formal operations if he simply used a systematic approach to eliminate the irrelevant variables in Piaget's pendulum problem. The study emphasizes the need for clear, workable standards for further research on formal operations. The task used, the subject's previous experience, and the definition of formal operations all affect the performance of subjects said to exhibit formal operations.

Robert A. Lengel and Robert R. Buell (1972) in the study 'Exclusion of Irrelevant Factors' investigated the growth in the logical operations of exclusion on science students selected randomly from grade VII, IX and XII. The students were from the lower socio-economic-status. They concluded that there is a gradual growth of the scheme of thought between grade 7 and grade 12. They did not notice any sex difference.

R.M.Misra (1973) investigated the role of hypotheses in problem solving among grade X science students. His study indicated that no sex-difference exist between the top group and the bottom group on the number of hypotheses emitted by them. It was also found that the problems were solved over a wide I.Q. range and many adolescents had found difficulty in testing hypotheses.

F. Somerville (1974) administered Inhelder and Piaget's (1958) pendulum problem on a sample of 276 ten to fourteen year olds individually and their responses were recorded verbatim. The author concludes, 'over all level of performance on the pendulum problem is strongly related to age, but not to sex or to the school attended'. The results, in general support Inhelder and Piaget's account of the transition from concrete to formal thinking.

Karplus, Karplus, Formisano and Paulsen (1975) gave both proportional reasoning problems and controlling variables problems to 13- and 15- year olds in seven countries. About 25% of the subjects used formal operations on proportional reasoning, while about 20% used formal operations on controlling variables. The relative difficulty of the two tasks were not consistent from one country to another, and the two tasks were not well correlated over the entire population. They concluded that the program used for teaching science and mathematics in each country influenced the likelihood of demonstrating formal reasoning ability. These findings parallel those of Lovell (1961) for schools within England.

Bonzy and Fox (1975) found that age interacted with the number of variables in a particular task such that two variables tasks (like Balance Beam) were solved by most 12- to 13- year olds, while tasks with multiple interacting variables (like Floating and Sinking) were seldom solved, even by 16- and 17- year olds.

Vaidya (1975) studied 'The Growth of Logical Thinking in Science During Adolescence' on a sample of 100 boys and 100 girls studying in grades VI to X matched on intelligence and socio-economic-status. They were observed solving a series of seventeen different problems. The main findings of this study are : (i) Except for occasional fluctuations, average performance on each problem increases with grade. Mean performance in most of the cases favour boys rather than girls, however, they try hard to equalise their performance as they move into higher grades. (ii) A given problem is solved successfully (or failed) over a wide I.Q. range both within and across the various grades. (iii) A given problem is solved in stages. (iv) Pupils commit a large number of errors while engaged in problem-solving. (v) The complex problem solving processes arise from simple thinking processes. (vi) Adolescent pupils are affected by the content of the problem than the nature of the problem, contrary to Piaget's view. (vii) Where as adolescent pupils are in a position to set up hypotheses, they are not in a position, contrary to Piaget, to test them which shows that their minds have not yet become experimental. (viii) The top group differed from the bottom group on all the five measures of adjustment, understanding of the problem and all the seventeen schemes of thought.

Joyce (1977) in 'A Study of Formal Reasoning in Elementary Education - Majors', found that subjects were most successful with the syllogism, and least successful with the pendulum problem. The pendulum task required stating and testing of

hypotheses and only one third of the subjects in this study were able to contend with the suggested variables in a logical and consistent manner.

Avinash Grewal (1978) investigated the relationship between 'Hypotheses testing ability and Creativity'. She developed a test containing problems having short answers from the areas of physics, chemistry and biology in which students were asked to give more than one way of solving a given problem. She also found significant correlations between hypotheses testing ability and creativity variables like fluency and originality.

Leela Menezes (1979) conducted a study on 'Exclusion of variables During Adolescence' using 4 Piaget type problems on a sample of 100 students of classes VIII, IX, X and XI (25 from each class). The age ranged between 12 to 17 years. She found: (i) The mean performance on all the problems show an increasing trend for stating and testing hypotheses with grade. (ii) All the problems are strongly correlated with each other. (iii) Using the top 25% and bottom 25% groups, it was seen that they differ significantly from each other in respect to variables : age and grade but not in intelligence.

Sandhu (1980) in a doctoral study, on the 'Factorial Study of Adolescent Thought' investigated the thinking processes of adolescents (N = 936) of rural area between the age group 11+ to 15+ using 15 Piaget type tasks along with 24 other variables and found : (i) The performance on Piaget type tasks increases with age during the formal operational period and the boys fair

better than girls at the respective age levels. (ii) Intelligence and academic achievement have direct bearing on adolescent thought. (iii) The development to formal thinking leads to better adjustment of the individual and vice versa. (iv) Eight significant factors were extracted through factor analysis of the data. These factors had accounted for 44% of the total variance operating among all the 34 variables taken for the study. The factors extracted were named as : General intellectual factor of adolescent thought, Academic achievement factor, Adjustment factor, Behavioural factor, Emotional factor, Temperamental factor, Group factor of adolescent thought and Social factor.

Mathur, M. (1974) investigated the 'Growth of Experimental Mind During Adolescence' on a sample of pupils studying in grades VI to XI ranging in age between 11+ to 16+. She found the performance on Piaget type tasks show an increasing trend with grade with occasional fluctuations on certain tasks. It was also found that the capacity to grasp the essence of the problem increases with grade.

There are other studies as well which have indirect bearing on this problem* because they investigate different aspects of formal reasoning. They are : Heidbreder, E. (1926), Russell, D.H. & Dennis, W. (1939), Bailey, R.W. (1941), Hyde, D. (1950), Cohen, J & Hansel, C. (1955), Buswell, G.T. (1956), Wheeler, D. (1958), Keel, D.A. (1960), Lovell, K. (1961), Kaslinge, R.J. (1961), Bruner, J.S., Goodnow, J.J. & Austin, G.A.

* Please see the appendix.

(1962), Case, [illegible] & Collinson, [illegible] (1962), Elkind, [illegible] (1962), Donaldson, [illegible] (1963), Anderson, [illegible] (1965), Stone, [illegible] (1965), Lovell, A. & Butterworth, J... (1966), Kudin, L... (1966), Gunnels, [illegible] (1967), Wollman, J. (1969), [illegible] (1970), Karplus [illegible] & Karplus, [illegible] (1970), Hart, [illegible] (1971), Kirkley – Trans [illegible] & Smith, [illegible] (1971), Lee, [illegible] (1971), Mackinnon, [illegible] & Renner, [illegible] (1971), Bult, [illegible] (1972), Arlin, [illegible] (1972), [illegible] (1972), Lewis, [illegible] (1972), Lunzer, Harrison & Davey (1972), Renner, J... & Stafford, [illegible] (1972), Mason & Johnson – Laird (1972), Wells, J. (1972), [illegible]ytright, [illegible] (1972), [illegible] (1972), Chetala, [illegible] (1973), Griffiths, [illegible] (1973), [illegible] (1973), [illegible]rni, [illegible] (1973), [illegible] (1973), [illegible] (1973), [illegible] (1973), Seitz, [illegible], Bynum, [illegible], Thomas, J. [illegible] & Steger, J... (1973), Blasi, [illegible] & Hoeffel, [illegible] (1974), [illegible] (1974), Dochorty, [illegible] (1974), Greybill, [illegible] (1974), [illegible] (1974), Karplus, [illegible] et al (1974), Kidder, [illegible] (1974), Lawson, [illegible] (1974), Morelans et al (1974), Doney, [illegible] (1974), Abramowitz, [illegible] (1975), Arlin, [illegible] (1975), Bautista, [illegible] (1975), Bater, [illegible] (1975), Cattrick, [illegible] (1975), [illegible]nnis (1975), Graybill, [illegible] (1975), Hathway, [illegible] (1975), Jurascheka, [illegible] (1975), Kenting, [illegible] (1975), Lawson, [illegible] & Renner, J... (1975), Rajput, [illegible] (1975), Raven, [illegible] & Guerin, [illegible] (1975), Sayre & Ball (1975), Sayre, [illegible] & Daniel, [illegible] (1975), Schwebel, [illegible] (1975), Valentine, [illegible] (1975), Waite, [illegible] (1975), Clayton, V. & Overton, [illegible] (1976), Germain, J. [illegible] et al (1976), Griffiths, [illegible] (1976), Karplus, [illegible] & Arons, [illegible] (1976), Ahun, [illegible] (1976), Lawson, [illegible] & Blake, [illegible] (1976), Linn & Levine (1976), Cooper, [illegible] et al (1977), Mortorano, [illegible] (1977), Cantu, [illegible] & Herron, J.D. (1978), [illegible]

(1978), Hollrand, W.J. (1979), Walker, [illegible] et al (1979), Sisoda, V. (1981), Marek, [illegible] (1981), Jurasechek and Grady (1981), and Lawson, [illegible] (1981). Still, all these studies when consolidated together do not appear to scratch the various schemes of thought developing during adolescence as enunciated by Piaget in his vast research programme which for the benefit of the research workers is reproduced below :

S. No.	Scheme	Experiments
1.	Combinations	Chemical combinations, in a system containing a substance to be coloured: a dye, an inhibitor, and a neutral agent.
2.	Proportionality	Equilibrium on a balance beam where the multiplicative relation between length & weight must be dealt with.
3.	Correlations and probability	Discovering the relations between a pair of imperfectly correlated variables (hair and eye colour).
4.	Conservation beyond empirical experience	Conservation of movement in a system containing some friction, i.e., rolling balls on a horizontal plane.
5.	Inversion and reciprocity coordinated in maintenance of equilibrium	Behaviour of liquid in communicating vessels (equality of water pushed out of one tube and into the other).
6.	Mechanical equilibrium	Hydraulic press (a more quantitative version of the preceding).
7.	Coordination of two reference systems	Snail moving on moving platform.
8.	Equilibrium of work mechanical proportion	Behaviour of wagon on variably inclined plane counter balanced by variable weight on pulley.
9.	Geometrical proportionality	Predicting size of shadow cast with objects varying in size and distance screen and source varying in distance.

10.	Compensation of interacting variables	Behaviour of balls on rotating platform, relation between weight and distance from centre in determining centrifugal motion.

As far as the knowledge of the investigator goes, not a single study has been made which utilises the above mentioned schemes of thought exemplified through their corresponding experiments on the same sample for the entire range of adolescence.

Concluding Statement

In sum, if the various findings of the studies directly and indirectly linked with this problem are aggregated and reflected upon, the following statements of tentative type can be safely made.

(i) Majority of the normal adolescents operate at the concrete operational level.

(ii) The adolescents who are in a position to state hypotheses are not necessarily in a position to test the stated hypotheses.

(iii) The ability to attack the problems positively increases with age and grade.

(iv) Through cluster analysis, it is possible to identify the concrete and formal operational pupils.

(v) The study of physics requires more of formal thought than chemistry and biology.

(vi) In the development of concept, mental-age and grade are more important than chronological age.

(vii) Significant relationship exists between academic achievement and creativity.

(viii) Concrete operational period merges with the beginnings of formal thought at possibly 13 or 14 years of age. 2 or 3 years later than the transitional period of Piaget.

(ix) It is only rarely that 'average to bright' junior school children reached the level of formal thought.

(x) The relevant cognitive content in the learner's cognitive structure facilitates the new learning in an increasing non-linear manner.

(xi) Children go through various stages of development with each level a necessary prelude to the following level.

(xii) There is a possibility of the existence of a fifth stage called 'problem finding stage' among adults. And, the fourth stage, called the 'problem solving stage' is a necessary condition for the development of the fifth stage. But all problem solvers are not problem finders.

Distinguishing Features of the Present Study

The present study attempts to investigate intensively one of the schemes of thought as propounded by Jean Piaget. Secondly, no study along these lines has been undertaken so far in this country as far as the knowledge of the investigator goes. Even at the cost of repetition, the other merits of the study are :

1. It attempts to develop a short reliable and valid test (and psychometrise it) for investigating this scheme of thought. This does not appear to have

been done so far.

2. The scheme of thought under study is being investigated in its maximal variation through a series of eight diverse problems along with other allied problems, for example, involving ability to exhaust possibilities as well as putting pupils in the wrong scent intentionally. That is, inviting wrong answers purposely.

3. This test instrument will facilitate reliable and valid comparisons among several groups of pupils under different conditions of schoolings for the studies which are yet to be concluded. At present, there is no instrument available.

4. A large number of outside variables have been included with a view to investigate the phenomenon in depth.

5. The data are subjected to a highly mathematical technique called the factor analysis - rarely used by the earlier workers.

6. A study of errors have been made, which occurs during problem solving.

7. It attempts to study the characteristics of the successful and unsuccessful problem solvers which has been done by very few workers earlier.

Chapter III

[illegible]

CHAPTER III

PLAN AND PROCEDURE

Opening Remarks

It is necessary to make a few remarks about the general orientation of this study. First, out of the several schemes of thought, only one is selected for intensive investigation. It is the 'Exclusion of Variables during Adolescence'. Secondly, as little was known about this variable, a few problems more were added to the test instrument which reflected the extent of thought of the adolescent pupils not only within the individual grades but also across the grades as well. In other words, according to Genevan psychology it is an aspect of formal reasoning where thinking is dominated more by the possibility rather than the reality. Thirdly, only this was not considered sufficient because it really informed little about the essential grasp of the problem. Here, the adolescent pupils were put intentionally on a wrong scent and their problem solving behaviour in this context was seen through a series of six test items. Fourthly, the Methode Clinique or Critical Method of exploration was not used because it was judged too time consuming. So naturally, resort had to be made to the questionnaire approach. Fifthly, attempt was

made to determine the reliability and validity of the test instrument which is generally not taken care of by the Piagetian workers in general. If ever it is, it is of very recent origin. Fifthly, as the computer facility was available during the closing stage of the study, it was decided to determine the mathematical structures of the problems contained in the test instrument through a highly mathematical technique called factor analysis. Seventhly, the present study included thirty nine variables and the data individually collected on these were subjected to factor analysis. [illegible]ly, it seemed possible to obtain other statistical relationships. So, the present study combined the best of the techniques of the developmental and the psychometric approaches, at the same time, losing a bit in the process which was beyond the circumstances of the investigator.

Section

Methods of Procedure

Sample and Subject

In this field experiment, a sample of about [illegible] pupils were initially drawn randomly among students of four middle and high schools of urban area, belonging to grades VI, VII, VIII, IX and X taking almost equal number of boys and girls in each grade. As this research aimed at studying the formal thought which is expected at the age range of 11 to 15 years, it was decided to take ten-year olds too in this study to see how they attend the formal problems and how successful they are in

solving them. Age and grade was controlled simultaneously. So as to get a homogeneous sample. For this, dates of birth of the students were noted down from the schools' registers and only the students of 10+, 11+, 12+, 13+ and 14+ year age levels and studying in grades VI, VII, VIII, IX and X respectively were picked up. The final sample drawn out consisted of 200 pupils (100 boys and 100 girls) who appeared in all the tests. The frame of the final sample was as given below :

Total Sample

200

100 boys

VI	VII	VIII	IX	X
20	20	20	20	20

100 girls

VI	VII	VIII	IX	X
20	20	20	20	20

Selection of Schools

The schools selected were all private institutions situated in the city (Mysore) and the students drawn for this study had English as their medium of instruction. All these schools followed the same syllabus, that is, the syllabus prescribed by the Karnataka Secondary Board of Education.

Tools Used

The general practice in this area of work is that, either the adolescent thought is investigated developmentally or psychometrically. The present study lies within the jaws of these two approaches. This point of view was missed by

Vaidya (1964) while investigating problem solving in science among certain groups of British adolescent pupils, using both the questionnaire as well as the individual approach. This made the interpretation of factors from the psychological angle too difficult. The same difficulty was experienced by Sandhern (1975) when he used only the questionnaire approach. In another study, Vaidya (1975) included as many as forty five variables. He however, did not include aptitude factors. Thus he had difficulty in interpretation of factors within the psychometric frame of work which, of course, was not his frame of reference. R. S. Shukla (1981) did try to improve upon the inclusion of variables. He did include one aptitude variable which related to space relations. This variable however, did not appear in the factorial interpretation of his study. In other words, it was lost somewhere. His study which comes close to the present study suffered from the following defects :

1. It included too many schools of thought.

2. Unlike Vaidya (1975) he did not pitch the internal structure of the problem against the external features of the problem which were deduced empirically.

3. Lastly, when all the factor analytic studies were consolidated and the appearance of factors and their psychological interpretation made, the position remained more or less the same

So, in this study it was decided to use the following tools. Even at the cost of repetion, which need not have been done in this chapter, they are mentioned here as follows :

1. Culture Fair (Free) Intelligence Test (Scale II, Form [illegible]) - Cattell and Cattell.

2. Junior Senior High School Personality Questionnaire (H.S.P.Q.) - Cattell and Cattell.

3. Differential Aptitude Tests :
   a. Abstract Reasoning,
   b. Mechanical Reasoning,
   c. Numerical Ability,
   d. Language Usage,
   e. Space Relations, and
   f. Verbal Reasoning.

They are now briefly described below.

1. Culture Fair (Free) Intelligence Test (Scale II, Form [illegible]) - Cattell and Cattell

The culture-free (or fair) intelligence tests aim to single out the most consistent core of basic mental capacity.

The culture-fair tests help in the separation of intelligence measurement from scholastic and general knowledge while maintaining a validity of basic intelligence measurement better than performance tests and at least as good as traditional pencil and paper tests.

Everywhere these perceptual tests, inspite of some strangeness and lack of 'face validity' as to their content, proved equal in validity to the traditional tests and superior in applicability to groups of varied racial and social background of students differing in areas of academic specialization.

There are 4 tests. Test (1) Series, Test (2) Classification, Test (3) Matrices and Test (4) Condition (Topology). Each, with 12 items to be completed in 3 minutes, 14 items in 4 minutes, 12 items in 3 minutes and 8 items in 2 1/2 minutes respectively.

This test was used in the present study to find out the I.Q. of certain groups of adolescent pupils and to determine its relationship with the other variables in the study.

3. Junior High School Personality Questionnaire (H.S.P.Q.) - Cattell and Cattell

The Junior Senior High School Personality Questionnaire (or H.S.P.Q.) is a standardized test that can be given within a class period, to single individuals or in groups, to yield a general assessment of personality development. The H.S.P.Q. measures fourteen distinct dimensions or traits of personality. They are :

1. Reserved/Warm hearted
2. Less intelligent/More intelligent
3. Affected by feelings/Emotionally stable
4. Undemonstrative/Excitable
5. Obedient/Assertive
6. Sober/Enthusiastic
7. Disregards rules/Conscientious
8. Shy/Adventurous
9. Tough minded/Tender minded
10. Zestful/Circumspect individualism

11. Self assured/Apprehensive
12. Socially group dependent/Self sufficient
13. Uncontrolled/Controlled.
14. Relaxed/Tense

These 14 traits have been found by psychologists to come near to covering the total personality. The reading level of the test is adapted to ages 11 or 12 through 18 years and scoring can be done rapidly by a stencil key. The test is administered without a time limit but can be completed in about 40-50 minutes for each form. There are four forms A, B, C and D.

H.S.P.Q. (Form A) was used in this study to find out the personality characteristics of adolescent pupils who formed the sample of this study and to determine the relationship between these scores and those on exclusion of variables.

3. The Differential Aptitude Tests (D.A.T.)

The Differential Aptitude Tests is a standardized, integrated battery consisting of eight tests (Verbal Reasoning, Abstract Reasoning, Numerical Ability, Space Relations, Mechanical Reasoning, Clerical Speed and Accuracy and Language Usage : Part I - Spelling and Part II - Sentences). It measures the abilities of boys and girls of junior-senior high schools as well as young adults out of school. The DAT represent a long and steady progress in the theory and practice of mental measurement.

The Differential Aptitude Tests are power tests. Each test of Forms A and B have separate booklets and the scheduling

of tests were scheduled around the class period. The exact time allowed for each test is as follows :

Verbal Reasoning	30 minutes
Numerical Ability	30 minutes
Abstract Reasoning	25 minutes
Space Relations	30 minutes
Mechanical Reasoning	30 minutes
Clerical Speed and Accuracy	
Part I	3 minutes
Part II	3 minutes
Language Usage	
Part I - Spelling	10 minutes
Part II - Sentences	25 minutes

Pupils record their responses on separate answer sheets which can be easily hand-scored or machine scored by special keys. Basic direction are printed on the test booklets which are read aloud by the administrator and silently by the persons being tested.

The Clerical Speed and Accuracy test which measures the speed and accuracy with which a pupil can identify the letter and number combination in a span of 3 minutes each for Part I and Part II, was not used in this study as it does not measure any intellectual ability of the pupil.

Brief descriptions of the other six tests used in this study are as follows :

Verbal Reasoning

The Verbal Reasoning test, is a measure of ability to understand concepts framed in words. It is aimed at the evaluation of the students ability to abstract or generalize and to think constructively, rather than at simple fluency or vocabulary recognition. The analogies form of test item is peculiarly appropriate for the measurement of reasoning ability. The particular type of analogies item devised for this test is especially useful because it provides very versatile items which are relatively complex but untricky.

Numerical Ability

The Numerical Ability items the understanding of numerical relationships and facility in handling numerical concepts. The problems are framed item-type to avoid the language elements of the usual arithmetic reasoning problems in which reading ability may place a significant role.

The Numerical Ability test is a measure of the students ability to reason with numbers, to manipulate numerical relationships, and to deal intelligently with quantitative materials.

Abstract Reasoning

The Abstract Reasoning test is a non-verbal measure of the student's reasoning ability. The series presented in each problem requires the perception of an operating principle in the changing diagrams. In each instance, the student must discover the principle or principles governing the change of

the figures and give evidence of his understanding by designating the diagram which should logically follow.

No premium is placed on visual acuity. In each case the task is generalizing the changes into the operating principles. That is, thinking with abstract symbols. Complexity is obtained from increasing conceptual difficulty. The differences are apparent, discerning why the pattern differs is the intellectual exercise.

The Abstract Reasoning test supplements the general intelligence aspects of the Verbal and Numerical tests. It involves the ability to perceive relationships in abstract figure patterns—generalization and education of principles from non-language designs.

Mechanical Reasoning

Each item consists of a pictorially presented mechanical situation together with a simply worded question. The items are presented in terms of simple, frequently encountered mechanisms that do not resemble textbook illustrations or require special knowledge.

The Mechanical Reasoning test may test one aspect of intelligence, if intelligence is broadly defined. A person who stands high in this characteristic finds it easy to learn the principles of operation and repair of complex devices.

Space Relations

The item type devised for the Space Relations test represents a combination of two previous approaches to

measurement of this ability. The ability to visualize a constructed object from a picture of a pattern has been used frequently in tests of structural visualization. Similarly, the ability to imagine how an object would appear if rotated in various ways has been used effectively in the measurement of space perception. The item type used combines the functions of these previous item types, since both factors are considered important in any useful definition of ability to think in spatial terms.

The ability to manipulate things mentally, to create a structure in one's mind from a plan, is what the test is designed to evaluate.

Language Usage

The Language Usage tests, Spelling and Sentences are more nearly achievement tests than any of the others. Their chief reason for their inclusion is because it provides a good estimate of a student's ability to distinguish correct from incorrect English usage.

Spelling

The words in the spelling section were from the test in Gates Spelling Difficulties in 3876 Words (1937). The words were further selected editorially for their prominence in everyday vocabulary. The incorrect spellings were those which the research of Gates and others showed to be most frequent errors.

Sentences

The Sentences section of Language Usage test is intended to measure the students ability to distinguish between good and bad grammar, punctuation and spelling mistakes.

Scoring of the above six tests were done as in the following table.

Table 1

Scoring Keys for Six DAT Tests

S. No.	Test	Maximum possible score	Formula*	Hand keys	Notes
1.	Verbal Reasoning	50	R	Rights only	One mark for each item number
2.	Numerical Ability	40	R-1/4W	Rights and wrongs	One mark for each item number
3.	Abstract Reasoning	50	R-1/4W	Rights and wrongs	One mark for each item number
4.	Space Relations	100	R-W	Rights and wrongs	Multiple marks were given for each item number
5.	Mechanical Reasoning	66	R-1/2W	Rights and wrongs	One mark for each item number
6.	Language Usage Part I - Spelling	100	R-W	Rights and wrongs	One mark for each item number
	Part II - Sentences	95	R-W	Rights and wrongs	Multiple marks were given for each item number

* R = Right
W = Wrong

Data on individual ages of the adolescent pupils were taken from the official records.

Section B

Developing the Test Instrument

Construction and Administration of Piaget Type Tasks

To study the thinking processes among certain groups of adolescent pupils, it was proposed to develop a short reliable and valid tool which would measure the following two variables (1) stating of hypotheses and (2) testing of hypotheses, interactively.

The following points were kept in mind while constructing the tasks. The problems should be :

1. As diverse as possible.
2. Novel, interesting and thought provoking.
3. General and not bookish, demanding any specialised knowledge.
4. Comprehensive. Language used should be clear and simple.
5. Of average difficulty.
6. Lastly, the number of problems should be small enough to ensure and retain interest, but large enough to adequately sample the thinking processes of the adolescent pupils.

Thus, a series of Piaget type tasks were constructed of which after preliminary try out of these tasks, only twelve tasks were finally selected after finding out the validity and reliability, for the main study.

For finding the reliability co-efficients, the scores of the pupils studying in IX grade were taken as it is then that most of the pupils begin to solve these problems quite substantially. The reliability co-efficient was determined by the test-retest method, with a time-gap of two months between the pretest and post-test. For validity, the external criterion was the scores of Abstract Reasoning (AR). The test-retest reliability and validity co-efficients of each item (problem) as found are shown in the following table.

Table 2

Reliability and Validity Co-efficients of the Twelve Problems

S. No.	Problem	Code	Relia-bility	Validity against Abstract Reasoning (AR)
1	2	3	4	5
I.	Questionnaire No. 1			
1.	The Flow of Liquid Through a Tube Problem	Q_1P_1(TCM)	.77	.272
2.	The Simple Pendulum Problem	Q_1P_2(TCM)	.41	.205
3.	The Lamp Problem	Q_1P_3(TCM)	.72	.357
4.	The Seed Problem	Q_1P_4(TCM)	.43	.453
II.	Questionnaire No. 2			
5.	The Flow of Liquid Through a Tube Problem	Q_2P_1(TCM)	.85	.067
6.	The Simple Pendulum Problem	Q_2P_2(TCM)	.71	.190
7.	The Lamp Problem	Q_2P_3(TCM)	.76	.266

1	2	3	4	5
III. Questionnaire No.3				
8.	Capital problem	[illegible]	.7[illegible]	.[illegible]7[illegible]
9.	Formulating questions problem	[illegible]	.77	.[illegible]6
10.	Questions involving going towards problem	[illegible]	.6[illegible]	[illegible]
11.	The [illegible] Trade problem	[illegible]	.[illegible]	.411
12.	The Worms problem	[illegible]	.77	.1[illegible]

As the various problems supposed to measure evolution of variables in particular and formal reasoning in general, were pitted against each other. For the purpose of facilitation of factorial interpretation for which no reliable and valid test is available, it was decided to include all the problems in this study a decision reason which appears to have justified itself, when the fifth chapter on 'Factorial structure of Adolescent Thinking,' was drafted.

These twelve tests were presented in the questionnaire form. For the sake of convenience and to elicit better response from the pupils, the tests were not administered [illegible] but they were presented in three separate questionnaires* of four, three and five tests each as follows :

1. Stating of hypotheses questionnaire consisted of the following four problems :

   1. Flow of water through a tube problem
   2. The pendulum problem

* See appendices 1, 2 and 3

3. The ramp problem

4. The same problem

II. Testing of hypotheses questionnaire consisted of the following three problems :

1. Flow of water through a tube problem

2. The pendulum problem

3. The ramp problem

III. Some interesting and funny questions questionnaire consisted of the following five problems .

1. Digital problem

2. Formulating questions problem

3. Inviting wrong answers questions

4. The magic card problem

5. The worms problem

These three questionnaires were administered in the regular classrooms and there was no time limit as such pupils were allowed to think as freely as possible and take as much time as they wanted.. However, to complete each questionnaire, children took between 45 to 60 minutes.

After the distribution of the questionnaire, the pupils were asked to fill-in the required information on the outer cover, that is, name, age etc. Then the instructions were read out aloud by the investigator along with the example and children were asked to follow it in their respective questionnaires. After making sure that all had followed what they were supposed to do, they were asked to go ahead with the other problems.

Limitations of These Test
Instruments

a. It does not test achievement in science or any of its specific branches.

b. The testing time of these tools were on the high side and had to be administered in three sessions.

c. It aimed at testing only the key thinking processes that cannot be observed directly.

d. It does not give hints and clues in the process of solving the problem and children are made to think for themselves.

Factorial Structure of
the Piaget-type Tests

To explore the existence of one of the Piagetian schemes of thought hypothetically named as 'isolation of variables', all the 15 measures of the Piaget type tests, collected from 300 pupils were subjected to factor analysis to study their factorial structure. For this, a correlation matrix* (15x15) was prepared.

Correlation Matrix

A correlation matrix (15x15) was prepared and was divided symmetrically by the diagonal and the total number of co-efficients of correlation when counted was 105. All were found to be positive except two, which were negative and insignificant. Of the 105 coefficients of correlation, 87 and 6 were found to be positively significant at 0.01 level

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* See Appendix B.

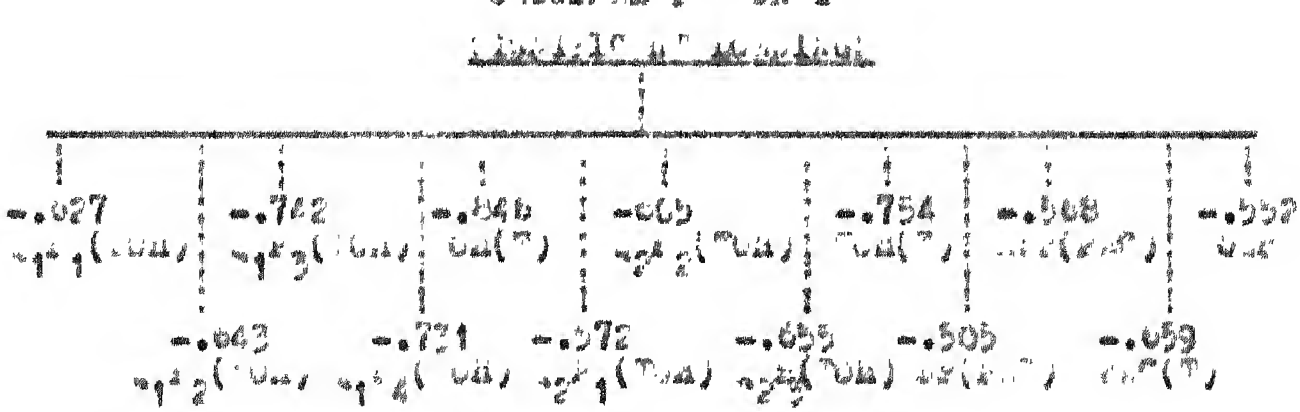
[illegible] .01 level respectively. 10 were positive and insignificant and 4 negative and insignificant.

Obtaining the factors

When the correlation matrix (15x15) was subjected to factor analysis, four significant factors having eigen values greater than one, were extracted and retained for varimax rotation. Results regarding both the original and varimax factor loadings are presented in appendices and figures respectively. The accumulated percentage of the total variance accounted for, by the factors I to IV has been found to be ranging from [illegible] - 71.3 and percentage of common variance accounted for varies between [illegible] to [illegible].

Interpretation of factors

In the present study the factor loadings below .35 of the variables on the various factors have been ignored while interpreting the factors.



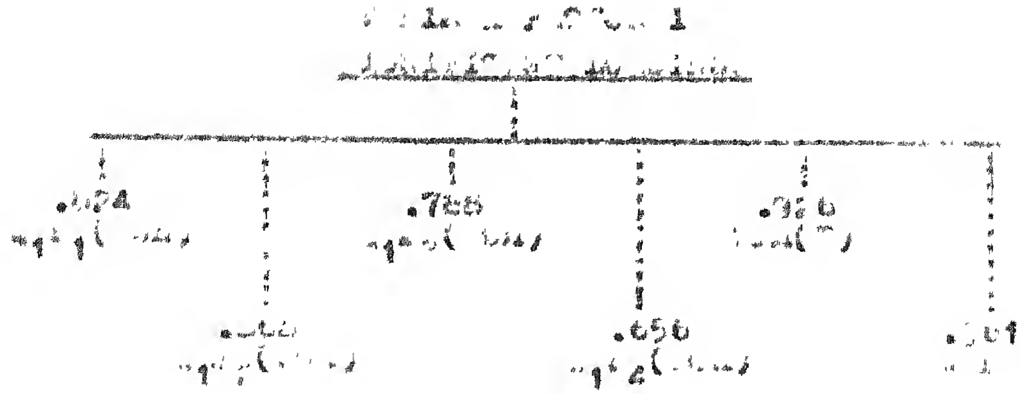


Fig.1
Significant Loadings of Original and Varimax Factor I

Factor I

Figure 1 shows significant loadings of the different variables on Factor 1 (both original and varimax rotated). In the first original Factor, out of the 15 variables, 14 were found to be having significant factor loadings and one (-.2[illegible]) insignificant loading. The highest loading for this factor was for the variable Stating of Hypotheses – Total (-.8[illegible]). Both, the percent of variance and cumulative percentage were found to be [illegible]. When the original factor was rotated by varimax, the highest loading was again seen on the variable Stating of Hypotheses – Total (0.926). So the Factor I is named as Stating of Hypotheses.

Contd.

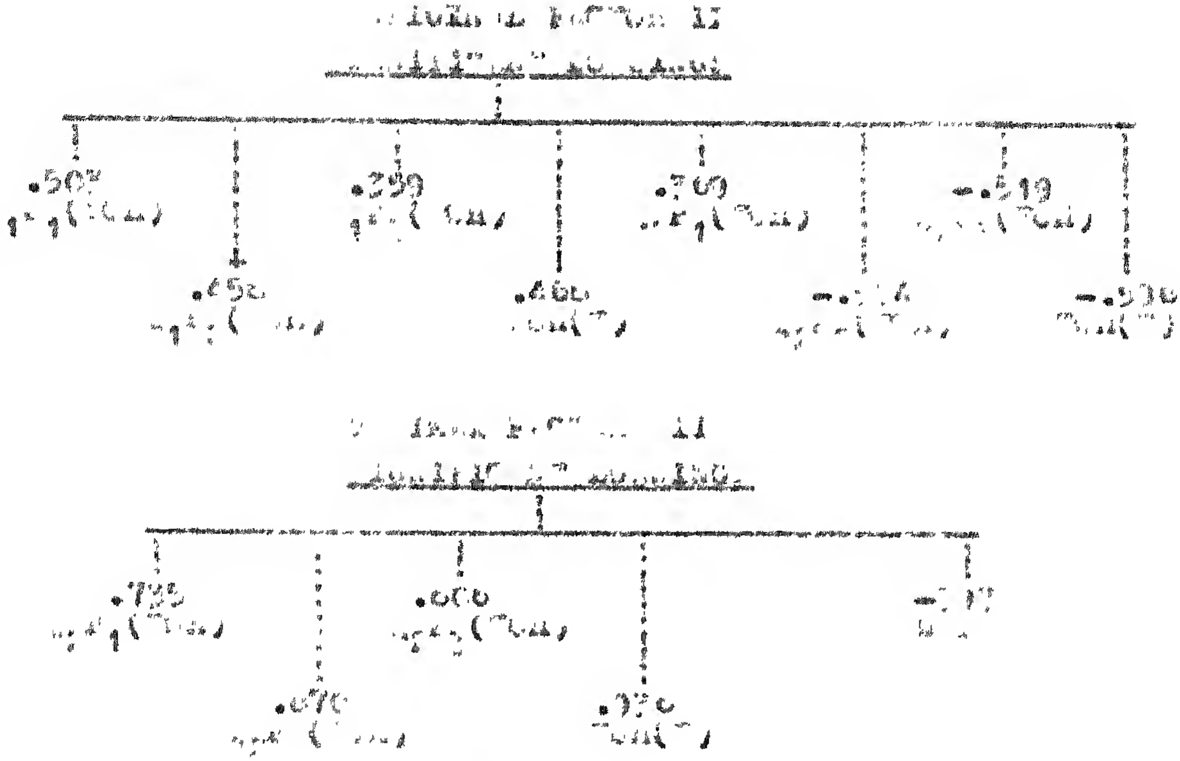


Fig. [illegible]
Significant Loadings of Original
and Varimax Factor II

Factor II

The Original Factor II shows significant loadings on eight variables : [illegible], [illegible], [illegible], [illegible], [illegible], [illegible], [illegible] and [illegible]. The percent of variance was found to be 14.1 and the cumulative percentage 37.6. When this was rotated, the Varimax Rotated Factor II showed significant loadings for only four variables : [illegible], [illegible], [illegible] and [illegible]. The highest loading is seen for the variable. Testing of Hypotheses – Total (.976). So, Factor II is named as Testing of Hypotheses.

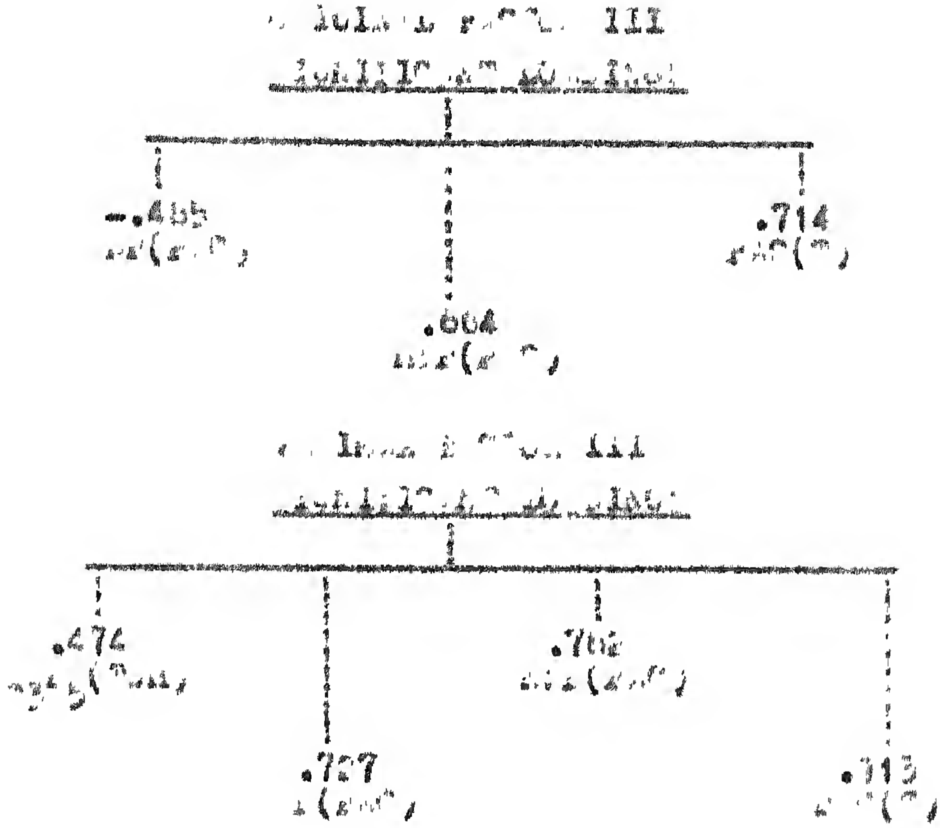


Fig. 3

Significant Loadings of Original on Varimax Factor III

Factor III

Significant loadings are seen on the variables : [illegible], [illegible] and [illegible] for the Original Factor III. The percent of variance is found to be 11.5 and cumulative percentage 64.2 for this factor. When rotated by Varimax, the significant loadings were seen on the variables [illegible], [illegible], [illegible] and [illegible]. The highest loading was for the variable [illegible] = .[illegible]15. So, the Factor III is named as Permutations and Combinations.

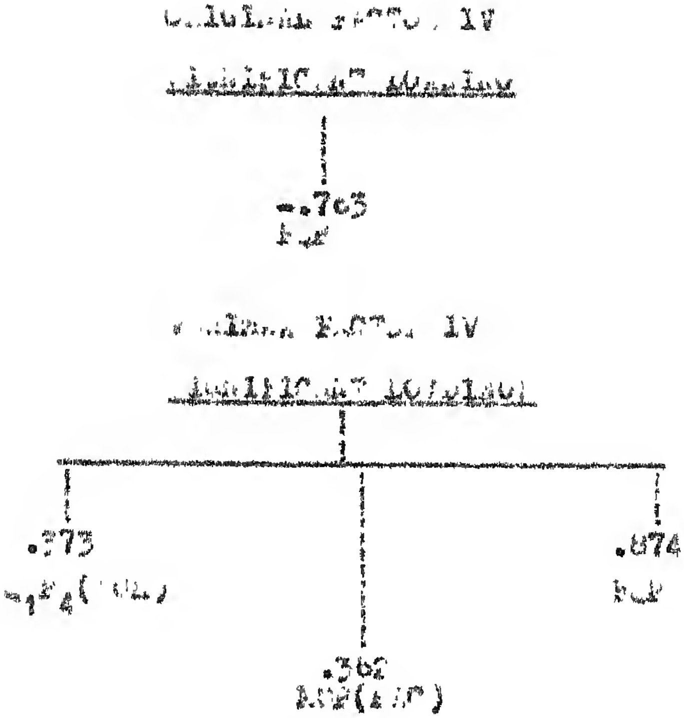


Fig. 4

Significant Loadings of Original and Varimax Factor IV

Factor IV

[illegible] (-.763) is the only variable found to have significant loading for the Original Factor IV. The percent of variance is found to be 7.2 and cumulative percentage 71.3. When rotated by varimax, significant loadings were seen on the variables : $_1F_4$([illegible]), [illegible]([illegible]) and [illegible]. The highest loading was for the variable formulating questions problem (.874). So, factor IV was named as Problem Sensitivity.

Fig. 5
Graphic Relationship Between the Four Factors and Their Corresponding Eigen Values

When these four factors were subjected to 'Screen test' as propounded by Cattell, the last two factors disappear and only the following two factors remain.

Factor I — Stating of Hypotheses

Factor II — Testing of Hypotheses.

Concluding Statement

An attempt mid-way between the clinical approach and the developmental approach using the questionnaire method is

made here. Secondly, only one schema of thought tentatively named Exclusion of variable out of the many hypothesized by Piaget is selected for intensive investigation. Thirdly, several problems/tasks were selected which were supposed to reflect formal reasoning whose one of the aspects was supposedly the Exclusion of Variables. Fourthly, the problems used in this study were presented the three separate questionnaires keeping in mind the factors of elegance and economy of space. Fifthly, not usually done but done in this study is the computation of the reliability and validity co-efficients of the problems. The reliability co-efficients range between .41 and .65 and the validity co-efficients between .067 and .454. Sixthly, at a later stage of this study it became possible to factor analyse all the problems (N=6) having more variables when seen from different view points (N=15). Using Principal Component Method four factors appeared out of which the first two were found to be Stating Hypotheses and Testing Hypotheses. Seventhly, the study sample comprised of 200 pupils (100 boys and girls each) drawn in equal numbers from grade VI to grade X studying in English medium private schools in Mysore which followed the same syllabus prescribed by the Karnataka Secondary Board of Education. On this sample factual information and data were obtained yielding 24 more variables. In all, the data on 39 variables relating to this study was obtained which were subjected to statistical analysis. The variables were : Age, Intelligence, Personality traits, Aptitude measures and Measures of Piaget-type tasks.

CHAPTER IV

ANALYSIS OF PROBLEM SOLVING BEHAVIORS
WITH
SPECIFIC REFERENCE TO THE SCHOOLS OF
[illegible]

CHAPTER IV

ANALYSIS OF PROBLEM SOLVING BEHAVIOUR WITH SPECIAL REFERENCE TO THE STAGES OF EXCLUSION OF VARIABLES DURING ADOLESCENCE

Introduction

According to Piaget, it is at the formal stage of mental development only, that the adolescent pupils are in a position to reason logically. Their thinking is then dominated more and more by the possibilities rather than the reality of the situation. In other words, they try to exhaust all possibilities through experimentation, if possible. It is this aspect of the problem which is the object of investigation intensively in this study. It is done in the following three ways: First, the hitherto considered scheme of thought is split into two separate variables namely, stating hypotheses and testing hypotheses. Secondly, both these variables are investigated separately as was done by R.Vaidya (1979). Thirdly, as the problem was not very clear at the beginning of the study, other variables were also included which in a way reflected some of the significant phases of formal thought, namely, (i) Permutations and combinations as manifested through the

two problems: digital problem and the magic case problem (ii) problem sensitivity as manifested by the formulating questions problem and (iii) grasping the essence of the problem as manifested through six funny but equally interesting problems which intentionally invited wrong answers. At a later stage of the study, the factorial structure of the tasks used clearly hited the existence of two factors separated out as stating hypotheses and Testing hypotheses. It is these two alone which receive major attention in this chapter. Further, the problems as used in this study are detailed in terms of manner of presentation, scoring, sample responses wherever relevant and summary of results. For effective presentation of data and results, both of them have been treated together across similar problems which are discussed under the following five categories.

Category 1 Stating of hypotheses

Incorporates the following four problems :

1. The flow of liquid through a tube problem
2. The simple pendulum problem
3. The ramp problem
4. The seed problem

Category 2 Testing of hypotheses

Incorporates the following four problems :

1. The flow of liquid through a tube problem
2. The simple pendulum problem
3. The ramp problem

4. The worms problem

In the last mentioned problem, pupils are not only expected to draw relevant conclusions but also, to suggest additional experiments, if any.

Category 3 Permutations and combinations

Incorporates the following two problems :

1. Digital problem
2. The magic seeds problem

Category 4 Problem sensitivity

Incorporates inviting questions on 'Cycle' whose answers pupils do not know.

Category 5 Grasping the essence of the problem

Incorporates six questions intentionally inviting wrong answers. This category shows the extent to which pupils really grasp the essence of the problem or the extent to which their thinking is governed by the content of the problem which is the dominant manifestation of thought at the concrete stage of mental development.

The Nature of Hypotheses

Very little is known about the origin of hypotheses in individual minds. Even at the moment of writing, it is a matter of conjucture, for, they deal directly according to Vaidya with the 'Varied acts of psychic creations during encounters with problematic situations'. Unless tested, they are like 'Castles in the air'. If literature is consulted,

several terms appear which inform vaguely about their origin, nature and functions: 'tentative ideas, tentative steps, floating ideas, trial ideas, untested explanation, tentative assumption, shrewd guesses, generalization, hunch, imaginative idea, mental tool, mental model and building of temporary bridges'. At their best, they not only make opaque situations transparent but also become grand generalizations when guesses prove to be successful. Whereas a given problematic situation may suggest several hypotheses, the ones which makes about half of the remaining hypotheses obsolete, are said to be the most powerful ones. The successful hypotheses either solves the problem or alters it specifically where nature is compelled to answer. In whatever context they are seen, they are characterized by 'unambiguity, simplicity, sharpness, pinpointedness, testability, conceptual clarity in the individual's head and bordering on rightness - wrongness'. Even being of suspect reliability and validity, they, under appropriate conditions both theoretical and practical either clarify themselves or generate as well as uncover, in the process, unknown knowledge and skills. In short, they enable us to see the same problem from several standpoints, new modes of experimentation making out a case either, for or against a point, anticipating or predicting new facts and concepts etc. Thus, there is interaction between the real and the hypothetical through a series of hits and trials leading to adjustments with 'no holds barred'. The present study therefore just attempts to study this phenomena still shrouded in mystery.

Category 1

Stating of Hypotheses

In the 1st category, as already referred to, four problems were finally selected and included. They are the flow of liquid through a tube problem, the simple pendulum problem, the ramp problem and the seed problem. After the practice problem on the drying up of handkerchief, the pupils were asked to state hypotheses as they arose in their individual heads. They were asked to number their ideas because this instruction went a long way in facilitating the scoring of responses. The first problem attracted as many as 23 hypotheses. Similarly, the frequencies for the other three problems were 18, 24 and 36, respectively. When seen in an aggregated manner a case clearly establishes itself showing that adolescent pupils on the whole see the experimental situation presented hypothetically in all possible ways regardless the incidence of the same when only individuals are considered.

Now consider the statement of problems as they were administered to the pupils and the hypotheses each of them attracted.

THE FLOW OF LIQUID THROUGH A TUBE PROBLEM

Have a look at the diagram given below :

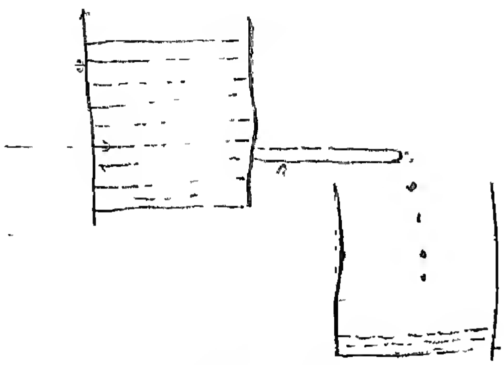


Fig. 6
The Flow of Liquid Through Tube

There are two beakers A and B. Beaker A contains as much liquid as you wish (want). It (beaker A) is placed at a higher level than the beaker B. A glass tube is fixed to the beaker A. The liquid flows from beaker A through the glass tube into the beaker B. Name all the factors upon which the quick filling up the beaker B depends.

The hypotheses stated by the pupils were :

i. Position of the glass tube fixed to the beaker A.

ii. Size of the hole of the glass tube.

iii. Length of the glass tube.

iv. Weight of the glass tube.

v. Shape of the glass tube (Straight or bent).

vi. Any obstruction (cork) in the glass tube.

vii. Viscosity of the liquid.

viii. Clear liquid.

ix. Amount of liquid in beaker A.

x. Temperature of the liquid in beaker A.

xi. Nature of the liquid.

xii. Colour of the liquid.

xiii. Size of beaker A.

xiv. Breadth (width) of beaker A.

xv. Height (depth) of beaker A.

xvi. Tilting beaker A (towards right).

xvii. Material of beakers A and B.

xviii. Thickness of beakers A and B.

xix. If the level of beaker A is lowered.

xx. If the level of beaker B is raised.

xxi. Tilting of beaker B (towards left).

xxii. Atmospheric pressure.

xxiii. Colour of the beakers.

THE SIMPLE PENDULUM PROBLEM

Have a look at the diagram of the Simple Pendulum :

Fig. 7
The Simple Pendulum

It consists of a string whose one end is attached to a hook and the other end to a bob. If you give it a slight push, it moves to and fro sideways. To put in other words, it moves from A to B and back to A. This is called ONE OSCILLATION (a complete movement). Now, name all the possible factors on which the oscillation of any simple pendulum depends :

The hypotheses stated by the pupils were :

i. Length of the string.
ii. Material of the string.
iii. Weight of the string.
iv. Elasticity (Flexibility) of the string.
v. Thickness of the string.
vi. Strength of the string.
vii. Size (Volume) of the bob.
viii. Weight of the bob.
ix. Colour of the bob.
x. Material of the bob.
xi. Shape of the bob.
xii. Force of the push given to the bob.
xiii. Size of the hook.
xiv. Height of the hook.
xv. Strength of the hook.
xvi. Colour of the hook.
xvii. Shape of the hook.
xviii. Amplitude.

-0-

[illegible]

Look at the diagram very carefully.

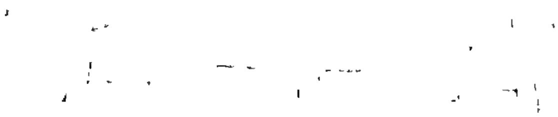


Fig. 6
The ramp

There is a ramp with a groove along which spheres can roll up and down. A target sphere is placed at the centre of the ramp. When another (rolling) sphere is released from the right (see the diagram), it rolls down the ramp, strikes the target sphere and makes it move up the ramp on the left.

The movement of the target sphere on any ramp depends on the following possible factors.

The hypotheses stated by the pupils :

i. Shape (curve/flat) of the ramp.

ii. Breadth of the ramp.

iii. Material of the ramp.

iv. Length of the ramp.

v. Height of the stand.

vi. The depth (shallow) of the groove.

vii. The nature of the groove.

viii. Any obstructive object in the groove.

ix. Size of the groove.

x. The material of the target sphere.

xi. Size of the target sphere.

xii. Colour of target sphere.

xiii. Weight of target sphere.

xiv. Hardness/softness of target sphere.

xv. Size of rolling sphere.

xvi. Push given to rolling sphere while releasing it.

xvii. Colour of rolling sphere.

xviii. Weight of rolling sphere.

xix. Hardness/softness of rolling sphere.

xx. Velocity of rolling sphere

xxi. Target sphere heavier than rolling sphere.

xxii. Rolling sphere heavier than target sphere.

xxiii. If both (rolling sphere and target sphere) are of same material.

xxiv. Force of air.

THE SEED PROBLEM

A farmer wishes to grow healthy plants. Name all the possible factors he should consider to make the seeds grow into healthy plants.

Factors stated by the pupils were :

i. Fertile soil.

ii. Presence of mineral salts in the soil.

iii. Presence of earth worms in the soil.

iv. Presence of nitrogenous substance (nodules) in the soil.

v. Quantity of soil.

vi. Loose soil ((a) ploughing the field every week, (b) ploughing the field with a pair of bullocks, (c) ploughing the field before planting).

vii. Colour of the soil.

viii. Quantity of fertilizers (Sulpher, Urea, Ammonium phosphate) added to the soil.

ix. Quality of manure (Cow dung etc.) added to the soil.

x. Optimum amount of manure added to the soil.

xi. Optimum amount of fertilizer added to the soil.

xii. Frequency (at least once a week) with which the manure is added to the plants.

xiii. Presence of bricks, stones beneath the soil layer.

xiv. Size of the land.

xv. Climate of the place.

xvi. Season when the seeds are sown.

xvii. Sunlight.

xviii. Rainfall of the place.

xix. Wind.

xx. Moisture in the air.

xxi. Irrigation facilities ((a) presence of well near the field, (b) watering plants every day, (c) watering the plants at the correct time).

xxii. Fencing the field ((a) to prevent cows, buffaloes etc. from eating the plants, (b) to prevent children from trampling and destroying them).

xxiii. Rotation of crops to prevent depletion of minerals in the soil.

xxiv. Removal of dried flowers and leaves.

xxv. Removal of weeds.

xxvi. Protecting the seeds from birds.

xxvii. Knowledge about the crop grown.

xxviii. Spraying of insecticides.

xxix. Spraying of pesticides (to kill locusts that destroy the crops).

xxx. Sowing the seeds in rows.

xxxi. Sowing the seeds by using tractor (mechanical).

xxxii. Spacing the plants.

xxxiii. The region (hilly or plain).

xxxiv. Presence of rodents (rats/rabbits) in the field.

xxxv. The time the farmer devotes to his plants and how much care he gives to them.

xxxvi. The physical strength (stamina) of the farmer.

Scoring

Scoring was done simply by giving one mark for each hypothesis stated. The total number of hypotheses stated pupil-wise and grade-wise was counted for each problem as well as for all the four problems together, which provided the measure for 'stating of hypotheses' as a whole.

Presentation of data

The data on the four problems grade-wise as well as sex-wise are reproduced below.

Contd.

Table 3

Means and Standard Deviations Grade-wise as well as Sex-wise for the four Problems of Stating of Hypotheses

S. No.	Problem	Sex	Grades VI Mean	VI S.D.	VII Mean	VII S.D.	VIII Mean	VIII S.D.	IX Mean	IX S.D.	X Mean	X S.D.
1.	The flow of liquid through a tube problem	B	6.05	2.781	8.00	2.616	9.55	2.564	9.05	2.259	9.70	0.733
		G	5.80	3.205	7.40	3.202	8.50	3.364	7.00	2.176	10.05	2.326
		B+G	5.92	2.965	7.70	2.907	9.02	3.000	8.02	2.423	9.87	1.717
2.	The simple pendulum problem	B	5.20	2.966	9.35	3.731	7.80	3.533	9.50	2.705	8.05	1.424
		G	4.80	2.931	7.75	2.935	6.10	3.766	7.05	1.986	9.70	1.922
		B+G	5.00	2.918	8.55	3.414	7.95	3.609	8.27	2.650	8.92	1.345
3.	The ramp problem	B	4.10	2.972	9.30	4.672	6.25	3.143	8.00	3.261	10.25	2.099
		G	3.30	2.975	8.35	3.313	5.60	3.672	7.65	2.852	9.70	1.976
		B+G	3.70	2.963	9.12	4.077	6.42	3.465	7.92	3.025	9.97	2.032
4.	The seed problem	B	6.75	4.102	10.95	5.781	11.75	4.654	8.25	4.126	20.95	4.026
		G	7.25	4.655	13.70	5.453	14.10	6.121	11.55	3.000	19.05	6.637
		B+G	7.00	4.338	12.32	5.722	12.92	5.581	9.90	3.934	20.00	5.723

Interpretation

All the four problems being open-ended, the following trends appear :

1. The range of scores for the four problems each taken individually varies from (1) 1-17 (2) 1-18 (3) 0-22 and (4) 0-31 respectively. This shows that the problems have attracted quite a wide spectrum of thought.

2. The mean performance on each of the problem both grade-wise and sex-wise increases with grade and indirectly with chronological age because the grade in this study was controlled.

3. Except on the seed problem, mean performance has favoured boys rather than girls provided fluctuations here and there are ignored. The reason here may be that the boys are attracted more by the physical science problems than the biological science problem.

4. The ability to state hypotheses reaches its peak in grade 1. This result is in conformity with the findings of Grewal, Sanger, Mathur, Sansakar and Vaidya. Generally speaking who have used more or less similar problems each inhering a continuous chain of reasoning.

5. The variability of the group decreases with grade and indirectly with age on the first three problems only. In other words, the various groups become increasingly homogenous on the variable of stating hypotheses, largely speaking.

Category 2

Testing of hypotheses

In the second category we already referred to, four problems were selected out of which the first three problems were similar in character. These three problems are : The flow of liquid through a tube problem, the simple pendulum problem, the ramp problem and the worms problem. In each of these problems, out of the many hypotheses emitted only two were selected from each problem. They are called variables in this study (B = 3rd = C). It is on these variables that the pupils had to carry out controlled experimentation hypothetically. When seen from the Genevan angle, these three problems are pitched at a higher level of abstraction, because of the mode of administration, here it being the questionnaire approach reasonably illustrated.

The write up of the fourth problem was radically different. Here, the data for four experiments were presented diagrammatically. The pupils were free to have a look at the data any way they liked. They were supposed to answer two questions by having close look at diagrams at serial numbers (1) and (3) and (2) and (4). They could verify by having a second look at the data if they so wished. In order to obtain the maximum performance, they were also required to answer whether another experiment was really necessary to answer the main problem. In case the answer happened to be

'yes', they were then supposed to suggest that experiment diagramatically. In short, this problem was framed in such a manner that it required very little of writing.

Now consider the statement of the problems as they were administered to the pupils.

THE RATE OF LIQUID THROUGH
A TUBE PROBLEM

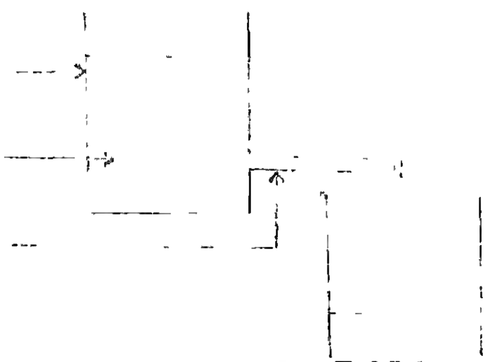


Fig. 9
The Flow of Liquid
Through a Tube

Liquid from beaker A flows through a glass tube and collects in the beaker B.

The amount of liquid collected in the beaker B in half an hour, say, depends on the following two factors alone :

1. Size of the hole in the glass tube
2. Level of water in the beaker A.

Suggest experiments to test these two factors.

THE SIMPLE PENDULUM PROBLEM

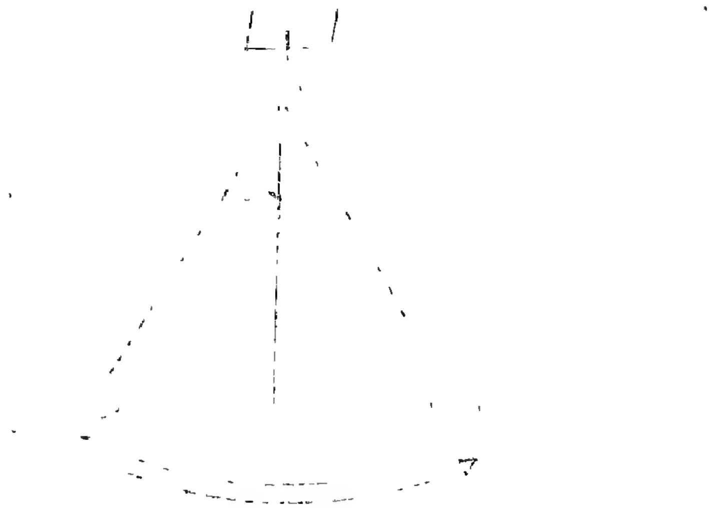


Fig. 10
The Simple Pendulum

The time taken for one oscillation of the pendulum depends upon the following faotors :

1. Volume of the bob
2. Weight of the bob

Suggest experiments to test these factora.

THE RAMP PROBLEM

Fig.11
The Ramp

The moving of the target sphere depends on the following factors :

1. The weight of the target sphere.
2. The nature of the surface of the groove.

Suggest experiments to test the above.

THE WORMS PROBLEM

A student of your age wanted to know how worms move about in Light and Moisture (wetness).

To solve this problem, he placed 20 worms in the centre of each of the four glass boxes under different conditions of light and moisture. For moisture, water was sprinkled on the bits of paper in the whole box or in half the portion of the box as required. Light was provided by the electric bulb to the required part of the box. The data are shown in the four diagrams given below. Your problem is to have a close look at each of these diagrams and reach a suitable conclusion. You are free to suggest any other experiment, if it might help to solve the problem clearly. It is also possible that the above mentioned student may have missed an experiment or two.

Contd.

Look at the diagrams carefully.

Fig. 12
The Movement of Worms in
Light and Moisture

1. What do you conclude from the diagrams (1) and (3)?
2. What do you conclude from the diagrams (2) and (4)?
3. Is any other experiment necessary? If yes, suggest the experiment with diagram. As regards practice, the same practice problem (The Drying up of handkerchief) was retained. It was presented as follows :

Practice Problem
THE DRYING UP OF HANDKERCHIEF PROBLEM

Example No. 1

One student 'A' said that 'Length' of the handkerchief was an important factor in its drying up. When asked to test this factor, he gave the following experiment :

He said, "I shall take three cotton handkerchiefs of different lengths, say of 10 cms, 20 cms, and 30 cms. In all other respects, they will be exactly the same. I shall dip all the three in water and spread them out in the sun. I will then note down the time taken for each handkerchief to dry up to the same degree. If the handkerchief of the smallest length (i.e. 10 cms.) dries up first and that of the largest length (i.e. 30 cms.) dries up the last, then I will conclude that 'length' of the handkerchief is an important factor responsible for its drying up. In case, all the three handkerchiefs of different lengths dry up at the same time, then I shall conclude that 'length' is not an important factor."

Example No. 2

Another student 'B' said that the materil of the handkerchief is an important factor. To test this, he must choose three handkerchiefs similar in all respects except the material of cloth e.g., cotton, wool and nylon.

He should then dip all the three in water and spread them on the ground. He should then note down the time they take to dry up. If all the three handkerchiefs dry up at the same time, it means that the 'material of the cloth' has no effect in their drying up. If, time taken for each to dry up is different, it means that the 'material' of the handkerchief is an important factor in drying up.

VERY VERY IMPOATANT INSTRUCTION

You are free to change the experimental materials. You are also free to suggest an experiment in any way you like.

anything you need for your experiment is supposed to be available. You have only to write its name.

Remember that you do not have to perform the experiment. You simply have to describe it in writing. You can also draw diagrams for explaining your point of view. Incidentally, this will also reduce your amount of writing.

You can easily avoid repetitive writing. But, at the same time, try hard to make your ideas as clear as possible for me. This you can safely do by numbering them. Elements and Aims of the Problems.

The reading of the first three problems shows that they are very similar to each other. So the objectives of the three can be stated together.

1. At what age level do the adolescent pupils begin to set up controlled experiments?
2. How is the solution of the problem attained as seen through the scoring key developed empirically?
3. How well can they test each of the given variables on each problem?

Scoring

After all the responses were read, it was decided that it was quite feasible to discern a four point rating scale for the first three problems and a three point rating scale for the fourth problem. The brief explanations of these points on the rating scale are :

0 -	Mark for totally incorrect answer.	for the first three problems
1 -	Mark for partially correct but not reaching the correct experiment.	
2 -	Marks for correct but fails to describe it properly, and	
3 -	Marks for clear and logical answer, where the pupils sets up the right experiment and describes it properly.	

Regarding the fourth problem, the scoring was done in two steps. That is, for the main problem and for the additional suggested experiments. The three point rating scale is as follows :

0 -	Mark for drawing a wrong conclusion.	for the main problem(first two questions)
1 -	Mark for partially correct conclusion.	
2 -	Marks for correct and logical conclusion.	

0 -	Mark for failing to suggest the right experiment.	for the additional experiments (Third question).
1 -	Mark for attempting and partially succeeding in giving the right experiment.	
2 -	Marks for suggesting the right experiment for solving the problem posed.	

When the scores were added for the three questions on this problem, the final score was 6 marks. When scored this way, the measure of this problem did represent the hypotheses testing ability of the pupils.

In short, the total score of the testing of hypotheses is 24.

The data is as presented below :

Table 4

Mean and Standard Deviations Grade-wise as well as Sex-wise for the Four Problems of Testing of Hypotheses

S. No.	Problem	Sex	Grades: VI Mean	VI S.D.	VII Mean	VII S.D.	VIII Mean	VIII S.D.	IX Mean	IX S.D.	X Mean	X S.D.
1.	The flow of liquid through a tube problem	B	2.30	1.922	2.25	1.505	2.65	2.159	4.35	1.268	4.70	1.302
		G	2.45	1.669	2.65	1.599	2.86	2.346	4.80	1.436	3.50	2.065
		B+G	2.37	1.779	2.45	1.729	2.75	2.227	4.57	1.357	4.10	1.807
2.	The simple pendulum problem	B	1.45	2.012	3.25	2.593	2.25	2.807	4.65	1.509	4.05	2.139
		G	1.20	2.016	3.65	2.750	3.55	2.438	5.10	1.447	5.05	1.761
		B+G	1.32	1.992	3.45	2.652	2.90	2.676	4.87	1.381	4.55	1.993
3.	The ramp problem	B	0.95	1.669	2.40	2.303	1.95	1.677	3.55	2.168	2.95	2.395
		G	0.95	1.761	2.90	2.449	3.35	2.390	3.75	2.314	5.30	1.261
		B+G	0.95	1.694	2.65	2.370	2.65	2.237	3.65	2.225	4.12	2.252
4.	The worms problem	B	1.60	1.166	2.10	1.744	2.35	2.134	1.80	1.673	1.90	1.252
		G	1.55	1.234	2.35	1.634	1.75	1.070	3.05	1.146	3.30	1.020
		B+G	1.57	1.196	2.22	1.702	2.05	1.634	2.42	1.551	2.60	1.707

The main findings across the problems are :

1. Like ability to state hypotheses, ability to test hypotheses shows an increasing trend with grade and indirectly with chronological age as grade was controlled.

2. With minor fluctuations here and there, the variability of the group across the grades as well as the four problems on the variable of testing hypotheses is heterogenous.

3. Contrary to the findings of A.Vaidya and T. Sandhu, sex differences with occasional fluctuations exist favouring girls, both across the grades as well as the problems. Here the reason well, may be, that boys and girls are treated equally in urban homes in Mysore. Secondly, the sample drawn in the case of their studies belonged to semi-rural and rural area in Himachal Pradesh and Punjab. It is just possible that the factor of regional differences may appear in sex differences either favouring boys or girls.

Attainment of Solutions

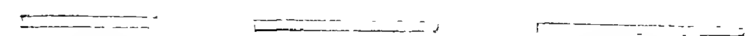
Due to the physical limitations of the testing facilities of the schools, it did not become possible to use the clinical method. Hence the data were collected in regular class situations using the questionnaire approach, where the three sets of questionnaires were especially designed for

this purpose. So, it is not possible to trace the growth of the solution as was done by the Genevans. However, it became possible to score the responses on a rating scale which was developed empirically i.e. after going through all the responses. In other words, only the key points (or the closest key points were discerned for scoring purposes. It is this view of the attainment of solution of the problems which is now reproduced below as originally obtained from the pupil responses grade-wise and sex-wise across the problems.

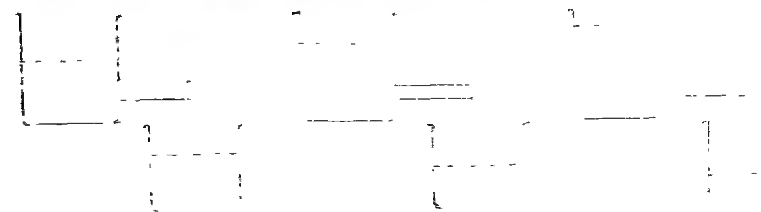
Contd.

Table [illegible]

Sample Responses at Four Levels (0, 1, 2, and 3) Grade-wise and Sex-wise on the Two Variables of the Flow of Liquid Through a Tube Problem

Grade	1st Variable - Size of the hole in the glass Tube	
	Zero Mark Level Responses	
	Boy	Girl
1	2	3
VI.	Vijay Kumar, I.Q. 114, Age: 10 y 4 m. Take two glass beakers and fix the glass tube to beaker A and fill 3/4 of the beaker with water and keep beaker B down. Through the glass tube water will come out.	Bharati, I.Q. : [illegible], 10 y [illegible] m. Take two glass beakers and fix a tube for beaker A and fill water
VII.	Praveen, I.Q. = 80, Age: 11 y 10 m. I shall take beakers of different lengths (1) 5 cms., (2) 3 cms., (3) 1 cm. In all other respects they will be equal. I shall take a beaker of 1 cms. fill the beaker 3/4 with water. Then I will note down the time to fill. If the size of the hole is big then beaker (A) will be filled quickly. Then I will note down the time taken to fill when the hole is small (A) beaker is filled with less water and (B) beaker with more water.	Ajitha, I.Q. = 107, Age: 11 y 1[illegible] m. I shall take three glass tubes of different sizes 5 cms., 6 cms., and 7 cms. and fix the glass tube in beaker A. The water collects in beaker B. The hole in the glass tube is not an important factor. Note down the time taken to fill the beaker B. If the level of water is same in beaker B, it is an important factor.  5 cms. 6 cms. 7 cms. Fig. 13 Size of glass tube is not same.

1	2	3
VIII.	Arjun, I.Q. = 39, Age 12 y 4 m. Take two sets of beakers of the same size and fill them with water. Now take two glass tubes of different sizes and fix one to the beaker A and other to B. A = 6 mm and B = 3 mm diameter. See how much time it takes for the water to flow from the big glass tube. Do the same with the other. If time taken is same then this factor is not important. If the time taken is different then I consider the factor is important.	Malitha, I.Q. = 52, Age 12 y [illegible] m. I shall take two pairs of beakers with glass tubes attached to its bottom. In the first pair let the size of the hole be 2 cms and in second 1 cm. Fill with same amount of water. The water flows through the glass tube note the time taken to fill both the beakers. I can conclude that if the time varies then this factor is not important. If the time is same then this factor is important.
IX.	Nil	Nil
X.	Nil	Vasuda, I.Q. = 59, Age 14 y 4 m. Take 6 beakers of same size and volume and with same level of water so it has same pressure. Take 6 glass tubes of different sizes (holes) and length see the filling of the water in the beaker. If the time taken for filling of the beakers is same then it is not an important factor.

1	2 (1 Mark Level Responses)	3
VI.	Pradhan Shekar, I.Q. = 12?, Age: 10 y 11 m Take two glass tubes of different sizes and if water comes out equal then the size of the hole is not important. If it comes different the tube is important.	Vanieri, I.Q. = 86, Age: 10 y 1 m. I shall take two glass tubes of holes 3 cms and 1 cm. in diameter.
VII.	Anup Lakhani, I.Q. = 11?, Age: 11 y 1 m. I take two glass tubes with different holes. Say one with 1 cms. and another hole 4 cms and fix them to 2 beakers A and fill liquid in both of them and let it pour into beaker B. If the tube with hole 4 cms. pours all the liquid quickly from beaker A to beaker B, then size of the hole is an important factor. But if both of them finish at the same time, the size of the hole in the glass tube is not an important factor.	Mitra Koltalsen, I.Q. = 117, Age: 10 y 1 m. I shall take three different size of the hole in the glass tube. Big hole (5 cms.), smaller one (3 cms.) and still smaller one (1 cm.). The beaker which has a tube of 5 cms. will send the liquid earliest because when there is more space more liquid will be filled and sent away. (2) If we take the smaller one (3 cms.) in which the size of the hole is lesser, less liquid will be filled in the tube and sent into beaker [illegible]. (3) Now, if we take the beaker in which the size of the hole is very small (1 cm.), the liquid from the beaker, through the tube will be sent drop by drop and hence beaker B will be filled less. That is the experiment that came to my mind.  Fig.14

1	2	3
VIII.	Jayaraj, I.Q. = 91, Age: 17 y. I shall take two beakers A and B and also I shall take 2 glass tubes 1 cm and 2 cms. First I shall see with the glass tube of 2 cms. and observe if it takes 1 hour to empty it. Then I shall test it with 1 cm. glass tube and find it takes 1/2 hours to empty it. This shows that the size of the glass tube is important.	Sabina, I.Q. = 112, Age: 12 y 1 m. I shall take two beakers A and B with tubes. 'A' having a big hole and 'B' small hole. I will connect this to two other beakers. If the water from A flows faster than beaker B, I conclude that the size of the hole of the glass tube is an important factor. All other factors should be same. If the flow is equal I say that is not an important factor.

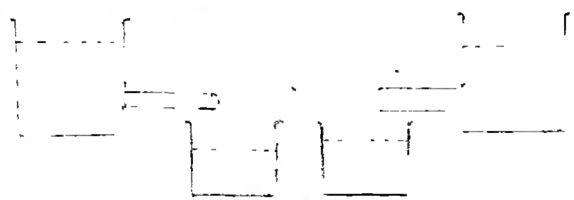


Fig.15

1	2	3
IX.	Chandra, I.Q. = 58, Age: 13 y 10 m. I shall take 2 glass tubes say about 1 cm. and other 2 cms.(holes). Take some water in beaker A. In half an hour if beaker empties all the water then we can conclude that it is also a factor necessary for quick filling.	Veena, I.Q. = 72, Age: 12 y 11 m. Take two glass tubes of two different diameters. Let it be 2 cms. and 3 cms. But the water flowed in half a hour will be equal. This shows that diameter of the glass tube is not an important factor.
X.	Venktesh, I.Q. = 89, Age: 14 y. I shall take two beakers. One A and other B. Let there be a tube of 2 cms.(width). Fill beaker A with water. Now see the amount of water collected in half an hour. Now take another/beaker A with 2 tubes of width 4 cms. and keep beaker B below A. Now see the amount of water collected	Pushpa, I.Q. = 110, Age: 14 y 7 m. I shall take three beakers of same size and volume. The level of water in all the three beakers is same. The size of the holes of the glass tubes must be in all different (for example 1, 2, 3/2 cm diameter). Even the three beakers B should be of same size. I must note the time from when the water is

1	2	3
	in beaker B. After half an hour, it is seen that more water is collected in beaker B in the 2nd experiment. This shows that the amount of water collected in beaker B depends on the size of the hole.	let to flow in the glass tube. Then I can know that the hole of 3 2 cms. diameter takes less time and the hole of 2 cms. diameter takes more time to fill the beaker B. If this is the case, size of the hole in the glass tube is an important factor ~~in~~ to fill the beaker B as soon as possible. But if the time does not vary to fill beaker B, then this factor is not a factor responsible for filling beaker B very quickly.

2. Marks Level Responses

VI.	Kamlesh, I.Q. = 89, 10 y 9 m. Take two glass tubes. One of 2 cms. and one of 1 cm and fix it to the beaker A. If water filled in beaker B is same then it means size of the hole is not an important factor. If the water	Padma, I.Q. = 56, 10 y 8 m. I will take two glass tubes, to test the importance of the size of the hole. One of 3 cms. and 1 cm. diameter. I shall fix the tube to beaker A. If I fix the tube of 3 cms. more to the beaker B. If I take the tube of 1 cm. hole the water will not come out faster. If the water collected in B. is same when I use different tubes then the size of the hole is not important. If the water collected in beaker B is different then the size of the hole is important.
VII.	Nayan, I.Q. = 63, Age 11 y 7 m. I shall take three glass tubes of different size holes; 1 cm., 2 cms. and 3 cms. and fix it up to three jars (beakers) and I pour water equal to all the three beakers	Anita, I.Q. = 80, Age: I shall take three sizes of glass tubes. One is 3 cms, one 2 cms. and one 1 cm. In all other respects they'll exactly be the same. I shall take the first tube of 3 cms. and

1	2	3

and if water starts flowing quickly and fill beaker b from the beaker where hole is big and if water comes slowly and fills beaker b less, then size of the hole in the glass tube is a main factor.

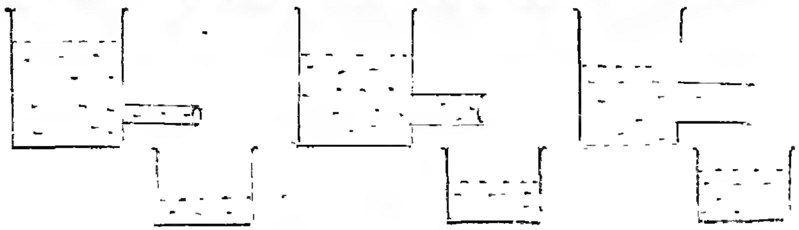


Fig. 16

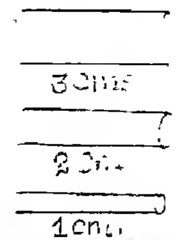


Fig.17

fix it to beaker with water. If the water flows quickly to the next beaker kept at the other end of the tube that means that the size of the hole in the glass tube is a good (important) factor. If the water will now flow quickly into the beaker and takes more time to fill, it means that it is not a good (important) factor.

VIII. Suresh Malani, I.Q. = 74, Age: 15 y 10 m.

Take three glass tubes of three different size holes (Fig.) If more water flows from thicker (bigger) glass tube and less water from thinner glass tube it is an important factor otherwise it is not.

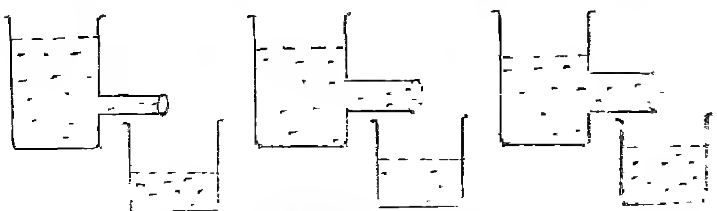


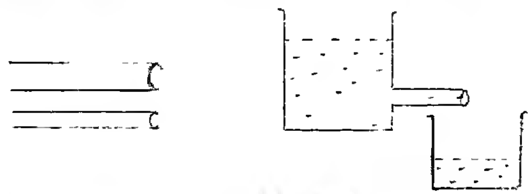
Fig. 18

Sangeetha Anttappa, I.Q. = 71, Age: 17 y.5m.

Take two beakers A, B. Now I will see that beaker A has a smaller hole in the glass tube and beaker B has a bigger hole. I shall then fill both the beakers with the same amount of water. After half an hour I will have more water than beaker A. If both the beakers have same amount of water in them then I conclude that 'size of the hole' is not an important factor.

1	2	3
1A.	Raj Singh, I.Q. = 75, Age 13 y. I shall take two beakers of the same shape and level of water sure and arrange as shown in figure. In one beaker the hole should be big and another smaller. How liquid flows into second beaker. Note how much liquid can pass through the tube and collect in the second beaker. If the level of liquid is same in both arrangements then size of the hole in the glass tube is not an important factor. If not, it is an important factor.	Sureka, I.Q. = 61, Age: 13.1 y. Take two beakers of the same size and the glass tubes of different diameters and keeping all other things same fix it to beaker A. If the beaker B is filled more from the beaker of the tube which has big diameter (hole), then the hole of the glass tube is an important factor. If it fills the same amount, this factor is not important.
1B.	Mohan, I.Q. 94, Age: 14 y 5 m. I shall take three beakers with tubes of same length but size of hole different. If the water collected in beakers B.C is the same then I conclude that size of the hole is not an important factor. If it is different, it is an important factor.	Suma, I.Q. = 69, Age: 14 y 2 m. Take three beakers A B C of same size. Let the size of the hole of the glass tube vary from each other. But the length should be same. Fill the beaker A B C with equal amount of water. If all the three beakers A B C fill the other beaker A, then the size of the hole in the glass tube is not an important factor. If the level of the water in beaker A raises then the size of hole in glass tube is an important factor.

3 Marks Level Responses

1	2	3
VI.	Nadsinb, I.Q. = 105, Age: 10 y 7m.  Fig. 10 Experiment : I will take two glass tubes, one of 3 cms. and another in size of 1 cm. holes. Then I'll fix the tube to beaker A. if the water collected in beaker B is same when two different tubes are used, then it is not an important factor. If the water collected in beaker B is different then the size of the hole is an important factor.	Reena, I.Q. = 100, Age 10 y 4 m. I shall take two glass tubes. One of 3 cms. and other of 2 cms. diameter of hole. Fix 3 cms. tube to the beaker A. the water in the beaker A flow into beaker B in 30 minutes. Then I fix the 2 cm glass tube to the beaker A. If the water collected is the same in the size of the hole is not important. If water collected is different then the size of the hole in the glass tube is important.
VII.	Naveen, I.Q. = 63, Age: 11 y 10 m. I will take three beakers and attach 3 kinds of tubes Eg. - small, medium and big and fill water in the beaker A. keep another beaker below the tube. If water comes out simultaneously and fills equally then size of the tube is not an important. but if water comes out fast from the big tube and slow from the medium and small tube and fills the beaker B unequally then the size of the hole is an important factor.	Leera, I.Q. = 89, Age: 10 y 3 m. I shall take three types of glass tubes about 1 cm., 2 cms., 3 cms. In all other respects they will be the same. Now put water in beaker A. It will flow in beaker B. I will note down the time and amount of water collected when the size of hole is 3 cms., 2 cms., and 1 cm. If water flows fast and more water is collected when the size of the hole is 3 cms. and water flows slowly and less water is collected when the size of the hole in the glass tube is

1	2	3

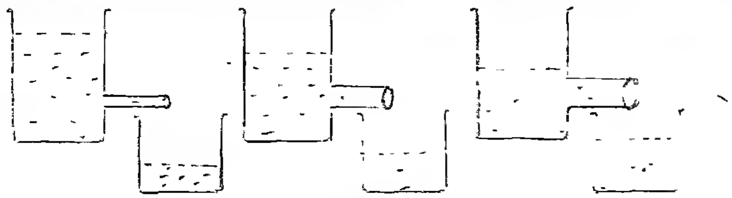


Fig. 20

1 cm., then I conclude that the size of the hole in the glass tube is an important factor for quick filling-up of water. In case from all three glass tubes of different sizes, water flows at the same time and equal amount of water is collected I conclude that it is not an important factor.

VIII. Anil Kumar, I.Q. = 99, Age: 12 y 8 m.

I shall take three pairs of beakers, with three tubes of 1 cm., 2 cms., and 3 cms. diameter, of the hole, attached beakers (A). And same amount of liquid is poured in all the three beakers ( ). If water collected in beakers (B) is same it is not an important factor. But if the amount of water collected in "B" is different when different tubes are used then I conclude that the size of the hole is an important factor.

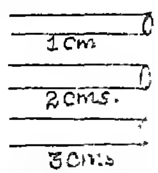


Fig. 21

Chandana Appaiah, I.Q. = 100, Age: 12 y 9 m.

Take two beakers of the same size and hole of the glass tube from which water flows must be different. Say, beaker A has a hole of 2 cms. and hole of beaker B is 3 cms. All other factors are the same. The water level should be same in both the beakers. Keep 2 beakers below A and B into which the water falls. Keep allowing the water to fall till half an hour. If the water filling from beaker A (that is) hole is 2 cms.) is less than the water falling from beaker B (that is, whose hole is 3 cms.) then it is an important factor. If it is same then it is not an important factor.

IX. Suresh, I.Q. = 103, Age: 14 y 1 m.

I shall take three glass tubes of same lengths but the size of the hole will be different. One of 2 cm and other of 4 cm diameter. In all other respects the two sets are same. If the water collected in beaker B is the same when we use different tubes then it means it is not an

Urchana, I.Q. = 84, Age: 12 y.

I shall take four beakers [illegible] and [illegible] and the other pair [illegible] and [illegible]. Beaker [illegible] has a glass tube with a hole having diameter of about 5 cms. Liquid from beaker [illegible] flows through the glass tube to the beaker [illegible] (Amount of liquid is same in both the beakers [illegible]). Then, I shall take beaker [illegible]. [illegible]

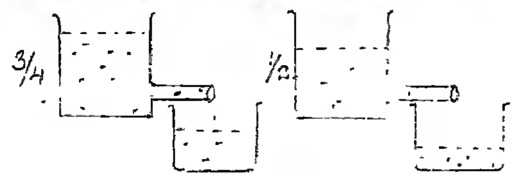
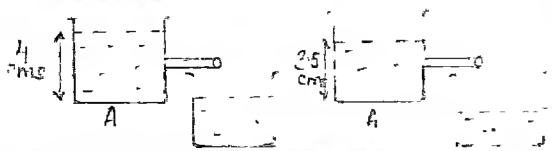
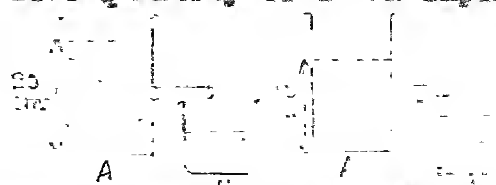
2nd Variable - Level of Water in the Beaker A

Zero Mark Level Responses

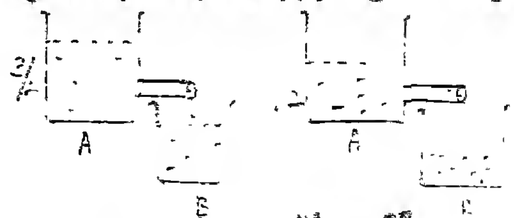
Grade 1	Boy 2	Girl 3
VI.	Sridhar, I.Q. = 88, Age: 10 y 2 m. I shall take two beakers. If the level of the water is different than it is not an important factor.	Rama Rani, I.Q. = 67, 10 y 11 m. I take two beakers and fix glass tube 3/4.
VII.	Raj Kumar, I.Q. = 85, Age: 11 y 4 m. Level of liquid in beaker A = 1 cms. and 2 cms.	Sumita Devi, I.Q. = 77, Age: 11 y. I am taking two beakers. The height of 5 cms. If the water in the beaker A is filled 4 cms. the water in the beaker B will be filled more. If the water in the beaker A is less then the water in the beaker B will be less.
VIII.	Srinivas, I.Q. = 91, Age: 11 y 4 m. The water level in beaker A is 3 cm. and the water collected in Beaker B is 2 cms. and the length of the glass tube which is fixed to the beaker A is 1 cm. and the glass tube fixed to the beaker is 2 cm. Therefore if water collects in beaker B in half an hour then the water collected varies from the other. Thus we conclude that the time of the most important factor.	Yesha, I.Q. = 84, Age: 11 y 5 m. All other factors should be same. Take a beaker and fill it with water. Take and their beaker, and again pour the water with the help of the tube then we see that the water may be equal by this we see that the level of water is necessary.
IX.	Nil	Nil

1	2	3
V.	Nil	Vasuda, I.Q. = 89, Age: 14 y 4 m. In the beakers of the same volume size and length foll the liquid in the beaker A then with different level see the time taken by the beakers to fill the beaker below, then of the time taken is less then the level is an important factor, and if the time is more than the level is not an important factor.

1 Mark Level Responses

1	2	3
VI.	Ramesh, I.Q. = 104, Age: 10 y 3 m. I shall take two beakers one with 3/4 and one 1/2 with water.  Fig. 22	Sureiha, I.Q. = 85, Age: 10 y 2 m. Take water 3/4 in beaker A and in another one 1/2 water. If the water goes to beaker B in 30 minutes it is not an important factor.
VII.	Naveen, I.Q. = 83, Age: 11 y 10 m. I shall take two beakers with different size (amount) of water e.g. 3.5 cms. and 4 cms. high. If the beaker completes the water simultaneously then the level of water in beaker A is not an important factor.  Fig.23	Armaity, I.Q. = 51, Age: 11 y 8 m. I shall take two beakers one of them 20 cm. and the other 10 cm. liquid. If the beaker A is filled in more quantity, of is an important factor, If beaker B is filled in less quantity of is an important factor.  Fig. 24

1	2	3
VIII.	Umesh, I.Q. = 88, Age: 11 y 3 m. I shall take two sets of similar experimental materials, except level of water in beaker A.	Lela, I.Q. = 100, Age: 12 y 10 m. I shall take 2 beakers A and B. The length of both is same. I shall fill the beaker A with 100 c.c. of water and B with 75 c.c. of water. I will see how much water it fills in half an hour. If it fills less, I shall conclude it is an important factor. It is same then I will conclude it is not an important factor.
IX.	Prakash, I.Q. = 75, Age: 13 y 1 m. Take 100 c.c. of water in a beaker A and 75 c.c. in beaker B. The size of the glass tube must be same. If the time taken is not equal it is an important factor.	Bindu, I.Q. = 76, Age: 13 y [illegible] m. I shall take two beaker A and B, where the level of the water, are different and all the other factors are same. If the time taken to fill the beaker B is same, then the factor will not apply but of the time taken for the filling up of the beaker varies then this factor with apply.
X.	Sriram, I.Q. = 70, Age: 14 y. I shall take two beakers and let it be filled with water at the varying levels. Fix a tube to beaker A. If there was beakers are filled on the beaker at the same time. Then this is not an important factor. If it varies of is an important factor.	Nil

2 Naive Level Responses		
1	2	3
VI.	Praveen, I.Q. = 86, Age: 10 y 4 m. I shall take two beakers. In one beaker of will take 3/4 and in another I will take 1/2 water. If water comes out same. It is not important otherwise it is.	Rama, I.Q. = 67, Age: 10 y 11 m. I shall take two beakers. In one I will full 3/4 and in beaker B I will fill 1/4. If water filled in beaker B is same. Then it is not an important factor. If water filled in the beaker is different it is important.
VII.	Sridhar, I.Q. = 96, Age: 10 y 11 m. I shall take a beaker namely A. I shall take another beaker namely B. I shall fix a glass tube of certain length to beaker B.	Jayanti, I.Q. = 93, Age: 10 y 11 m.  Fig. 25 I shall take two beakers with 3/4 and 1/2 water. If the water collected in beaker (B, B) shows same level. Then it is not an important factor. If the water collected in beaker B is different levels then it is an important factor.
VIII.	Prasanna Kumar, I.Q. = 82, Age: 12 y 6 m. If the level of water in beaker B is same when I use different levels of water in beaker. A then the level of water in beaker A is not an important factor. If the level of the water in beaker B varies, when I	Kiran, I.Q. = 91, Age: 12 y 7 m. I shall take two beakers A and B and fill them with different quantity of liquid. Then I will note the time taken for beaker B's filling. If the beaker B fills at the same time, I shall conclude that the level

1	2	3
	use different levels of water in beaker A it is an important factor.	of the liquid in beaker A is not of important factor. If one beaker fills quickly than the other, then I shall conclude that the level of liquid in beaker A is an important factor.
1.	Ramesh, I.Q. = 89, Age: 13 y 9 m. Keeping all other factors same except the level of the liquid in beaker A, if the water collected in the two beakers (B) is same, then it is not an important factor. If the water collected in the beakers varies then, it is an important factor.	Samantha Kumari, I.Q.= 76, Age: 13 y 10 m. If water collected in 2 beakers is same then it is not an important factor. If it varies then it is an important factor, when two different levels of water are used in 2 beakers A with the same tube.
2.	Vijendra, I.Q. = 89, Age: 14 y 5 m. I shall take four beakers. All identical for two I shall fix same size tubes and fill in one 2/3 and another 1/3 with water. If water collected is same level in the other beakers it is not an important factor.	Smitha, I.Q. = 93, Age: 14 y. Take two beakers of the same size and fill in it with water of different levels. First beaker is filled 3/4 and in second beaker 1/4 of level. If the water filled in beaker B is same, then the level of the water in beaker A is not an important, factor. If the water in beaker B is varied then the level of water in beaker A is an important factor.

3 Marks Level Responses

1	2	3
VI.	Ramesh, I.Q. = 104, Age: 10 y 3 m. I will take two beakers. One filled 3/4 water and the other 1/2. Then I will fix the tubes to the beakers. If water collected in Beaker A is same then level of water is not an important factor. If it is not then same then the level of water in beaker A is an important factor.	Uttaiah, I.Q. = 113, Age: 10 y 7 m. I shall take two beakers. In one fill 3/4 level and another 1/2 level of water. If water filled in beaker A is the same then it is not an important factor. If it fills on different levels that mean that this factor is important
VII.	Sri Ram, I.Q. = 103, Age: 11 y 10 m. I shall take four beakers A, A_1, B, B_1 and in A and A_1 water will be filled at different levels, but the tube will be of same size. After half an hour, water collected in beakers B and B_1 is noted. If they are same it is not an important factor. If it is different it is an important factor.	Shobha, I.Q. = 107, Age: 11 y 1 m. I shall take two beakers which have water upto a height of 30 cms. and 15 cms. in it. In all other respects they are similar. If the water collected in beaker B is in the same level it is not an important factor. If the water collected in beaker B is different level, then it is an important factor.

Fig. 2e

1	2	3
VIII.	Ashok, I.Q. = 95, Age: 1? y. 7 m. Take two beakers A and B. Take the liquid in beaker A = 3/4 and in beaker B = 1/2. Then allow the water to go through the glass tube. If the water in beaker B collected shows different levels than the liquid in beaker A is an important factor. If it shows same level in B then I conclude it is not an important factor.	Rabina, I.Q. = 112, Age: 1? y 1 m. I will take two beaker A and B having glass tubes. A having more liquid and B having less liquid. I will connect this to two other beakers. All other factors should be same. If the level of water collected is not equal I conclude that the level of liquid in beaker, A is an important factor. If the level of liquid collected in the beakers are equal it is not an important factor.
IX.	Sharif, I.Q. = 113, Age: 13 y. I shall take three beakers of the same size, let the holes. If the glass tube be closed by corks. In beaker A fill it with water completely upto the brim. In beaker B let the level of water be 3/4 of the beaker. In beaker C level of water be 3/4 of the beaker. In beaker C let the water be 1/2 of the beaker. Remove the cork of each beaker for a definite period (half an hour) and then out flowing water is collected in the corresponding beaker a, b, and c respectively. If it is observed that the beaker 'a' there is maximum amount of water and in 'c' least amount of water. The experiment proves that the level of water is important. If the same amount of water is collected in a, b, c than the level of water in 'A' is not an important factor.	Poornima, I.Q. = 104, Age: 13 y. Take two beakers of equal sizes let one have 3/4 of the beaker filled with water. Let another have 1/2 of the beaker filled with water. Then in beaker 'A' if the water collected is same of when we use beakers with different volumes of water, than the level of water is not an important factor. If the water collected is different when we use beakers with different volumes of water of than the level of water in beaker 'A' is an important factor.

1	2	3
4.	Satish, I.Q. = 103, Age: 14 y. 1 m. In first set take 3/4 of beaker if filled with 3/4 liquid and in the second set take 1/2 of the beaker A filled with liquid. But the glass tubes of both set should be of same length and size of hole. If the amount of liquid in beaker B is same then this factor is not important. If it varies for the two sets then this factor is important.	Sujatha, I.Q. = 119, Age: 14 y 6 m. Take three beakers, A_1, A_2 and A_3 with different level of liquid. Let the size of the beakers be same. Let all the other factors the hole of the glass tube attached etc., be kept at same levels water to flow from A_1 to B_1, A_2 to B_2 and A_3 to B_3 at the same time. Keep observing. After half an hour see the levels of water filled up in beaker B_1 and B_2 and B_3. If the levels are same in all, then this factor is not important. But if the levels differ then this factor is considered important. If the levels are same in all the three it is not important.

Table 6

Sample Responses at Four Levels (0, 1, 2 and 3) Grade-wise and Sex-wise on the Two Variables of The Simple Pendulum Problem

1st Variable - Volume of the Bob		
Zero Mark Level Responses		
Grade 1	Boy 2	Girl 3
VI.	Vijay, I.Q. = 114, Age: 10 y 1 m. Take a bob for the string. You push and the box will move.	Mallika, I.Q. = 96, Age 10 y. Take two bobs of 3 cm + 2 cm and weight of the bob and volume of the bob 100 gms. and 50 gms.
VII.	Raj, I.Q. = 65, Age : 11 y 4 m. Take three bobs. One small and another big and third one very big. Take three bob weight of (1) 200 gm. (2) 300 gms. (3) 400 gms. If the weight of is more than the bob will move show, that is not an important factor.	Nil
VIII.	Rajesh, I.Q. = 91, Age: 12 y 6 m. I suggest that if the volume of the bob is heavier than the oscillation will be show. If the volume of the bob is less in weight than it can move frequently from A to B without any difficulty. I say that if the string is athick then there will be no problem for the bob. If the string is long the oscillation will be move.	Gladis, I.Q. = 85, Age: 12 y. Take simple pendulum and let the length of the string, the weight of the pendulum is same. The string must be in same length. If the time taken for 1 oscillation is same, we can conclude that the volume of the box varies.

	1	2	3
IV.	Nil		Veena, I.Q. = 72, Age: 12 y 11 m. Take two bobs and string of the same size. It takes the same time for both the bobs, because the materials of the bob is same and size of string is same.
V.	Vasudev, I.Q. = 66, Age: 13 y. 10 m. Let the string be of same length, let one be wood and other be iron, make their, height same and the volume of both will then differ.		Nil
		1 Mark Level Responses	
VI.	Deepak, I.Q. = 95, Age: 10 y 1 m. Take two bobs of different size. One of 3 cms. diameter and the other of 1 cm. diameter		Rema, I.Q. = 67, Age: 10 y 11 m. Take two bobs 3 cms. and 2 cms. diameter.
VII.	Daniel, I.Q. = 80, Age: 11 y 10 m. Take two bobs, one with a diameter of 1 inch and another with a diameter of 2 inch and attach to the string.		Ajothe, I.Q. = 107, Age: 11 y 1 m. I shall take three bobs which is 4 cms., 5 cms. and 6 cms., when the time taken for one ocillation is different the volume of the bob is an important factor.

Fig. 27

1	2	3
VIII.	Anil, I.Q. = 93, Age: 12 y 8 m. If the time taken for one oscillation is the same when I use 2 bobs of different volumes. I conclude that the volume of the bob is not an important factor. If the time taken for one oscillation varies then I conclude that the volume of the bob is an important factor.	Vinutha, I.Q. = 86, Age: 12 y 9 m. Take two pendulumers. Let one bob be 4 cms. and other be 6 cms. Take down the time taken for one Oscillation. If the time will be same. This is not an important factor.
IX.	Nil	Nil
X.	Madhukar, I.Q. = 85, Age: 14 y 4 m. I take two bobs one of 2 cms and 3 cms. and is made of wood and steel. Here volume is different but wt. is same. So I conclude that volume important.	Anita, I.Q. = 99, Age: 14 y. Take two bobs of different volumes. If the time taken for one oscillation is the same, then, the volume of the bob is an important factor. If the time taken is different then it is not an important factor.
	2 Marks Level responses	
VI.	Mohan, I.Q. = 120, Age: 9 y 10 m. Take two bobs. One of 3 cms. diameter and the other of 1 cms. diameter. If the time taken is same for one oscillation is same. I conclude that volume of bob is not an important factor. If the time taken for one oscillation is different. I conclude that volume of bob is an important factor.	Meena, I.Q. = 100, Age: 10 y 8 m. Take two bobs one of 3 cms. and other of 1 cm. diameter. If the time taken for one oscillation is the same then it is not an important factor. If the time taken for one oscillation is different it is an important factor.

1	2	3
VII.	Anil, I.Q. = 89, Age: 11 y 3 m. I shall take three bobs of different volumes and of I find oscillation is same for three then it is not an important factor. If the oscillations vary then it is an important factor.	Smita, I.Q. = 89, Age: 11 y 4 m. I shall take two bobs of different volumes i.e. 1 cm, 2 cms. and 3 cms. (diameter) and tie it in a string which is fixed to a hook. The push it. If the oscillation for the small bob is more or less than the volume of the bob is an important factor. If an the three bobs take same time, then it is not an important factor.
VIII.	Nil	Asha, I.Q. = 100, Age: 12 y 10 m. Take two bobs one wood and one steel of same weight. (different volumes). Take one oscillation with the steel one and note the time again. If it is different of shall conclude that the volume is an important factor. If it is same, I shall conclude it is not an important factor.
IX.	Yogesh, I.Q. = 81, Age: 13 y 5 m. I shall take three bobs of different volumes but on all other aspects they will exactly by the same. If the time taken for one oscillation is same than I shall conclude that the volume of a bob is not an important factor. If it is different than the volume of the bob is an important factor.	Mohini, I.Q. = 75, Age: 12 y. Take two bobs of different volumes. One of 3 cms. and other is 2 cm. in diameter. If the time taken for one oscillation of the pendulum will be same then the volume of the bob is not an important factor. If the time taken for one oscillation of the pendulum will be different. Then the volume of the bob is an important factor.

1	2	3
V.	Nagraj, I.Q. = 103, Age: 13 y 11 m. Take two bobs of different volumes. Then see the oscillations of the bob. If there is difference of the bob is a factor on which the time taken. For one oscillation depends upon. But of the same time taken is the same, then the volume of the bob is not an important factor.	Vasuda, I.Q. = 89, Age: 14 y 4 m. I shall take three bobs of different volumes but all other factors should exactly be the same. If the time taken for one oscillation of the pendulum is the same, then the volumes of the bob is not an important factor.

3 Marks Level Responses

1	2	3
VI.	Madaiah, I.Q. = 105, Age: 10 y 2 m. I will take two bobs. One of 3 cms. diameter and another 1 cm. If the time ~~xxx~~ taken for one oscillation in both the cases are same than the volume of the bob is not an important factor. If the time taken is different, then it is an important factor.	Jayashree, I.Q. = 97, Age: 10 y 6 m. I will take two bobs one of 3 cms. and another 1 cm. diameter. If the time taken for one oscillation is same than it is not important. If the time for one oscillation is not same then it is an important factor.
VII.	Kumaran, I.Q. = 116, Age: 11 y. I shall take three bobs of diameters, 3, 4 and 5 respectively. Then I will tie a string to each of these bobs. I shall tie the other end of the string to a hook of each of the three bobs. The I shall push each of the bobs with the same force. I shall see which bob stops first and which	Shobha, I.Q. = 107, Age: 11 y 2 m. I shall take three bobs which are 1 cm, 4 cms. and 7 cms. in diameter. Fix it to string and note the time taken for one oscillation. If the time taken is same, it is not an important factor. If the time taken is different it is an important factor.

1	2	3
	bob stops last. If the bob which has its volume as 3 diameter stops last ~~the bob which has its~~ ... Then I shall ~~diameter~~ that volume of the bob as an unimportant factor.	

Fig. 28

VIII.	Arjun, I.Q. = 99, Age: 12 y 4 m. I shall take two bobs different in volume but similar in all other respects and when both are oscillated. If the time taken for both for one oscillation is same then of is not an important factor otherwise it is.	Margret, I.Q. = 61, Age: 12 y 9 m. I shall take two bobs of different material (wood and steel of 2 cms. and 3 cms.) in diameter respectively. Of same weight. I shall move both the bobs and note the time taken for one oscillation. If the time taken does not differ then I shall conclude that volume of the bob is an important factor.
IX.	Bickie Thomas, I.Q. = 69, Age: 13 y 10 m. Set up three pendulums of constant length but having bobs of different volumes but of same weights. Using a stop clock calculate the time taken for one oscillation. If the time taken for one oscillation is same then it is not considered, as an important factor but of the time taken for one oscillation varies for the three pendulums, then it is considered as an important factor.	Archana, I.Q. = 64, Age: 12 y. I shall take a pendulum in which the length of the string is same as in the other pendulum. But the volume of the bob is 2 cms. Then I shall note down the time taken for one oscillation. Now I shall take another pendulum, in which the length of the string is same as in the pendulum. But the volume of the bob is 2 c.m. I shall note down the time taken for one oscillation. Now if the time taken for one oscillation

1	2	3
		is different in the pendulum then the above factor is an important factor. But if the time taken for one oscillation is different then the above factor is not an important factor.
4.	Shekar, I.Q. = 106, Age: 14 y. I shall take three bobs of different volumes but all the other factors should exactly be the same. If the time taken for one oscillation of the pendulum is the same then the volume of the bob is not an important factor on which one oscillation depends on. But of the time taken for one oscillation of the pendulum is different then the volume of the bob is an important factor on which one oscillation depends upon.	Shobha, I.Q. = 113, Age: 14 y. I will take two bobs, one wooden and one iron of some weight but different volumes. I will attach string of same length. If time taken for one oscilla-tion is same for both then this factor is not important. It is varies, then it is important.

2nd Variable - weight of bob

Zero Mark Level Responses

VI.	Pradhan Shekar, I.Q. = 123, Age: 10 y 11 m. Take the bobs of different size and it is different.	Mallika, I.Q. = 98, Age: 10 y. Big bob is heavier than the small bob.

1	2	3
VII.	Umesh, I.Q. = 84, Age: 11 y 2 m. I shall take the two bobs of different weights. If we push the light bob attached to the pendulum, it will take less time for one oscillation. If the bob is heavy it will take more time for one oscillation. This shows that the weight of the bob is an important factor.	Nirmala, I.Q. = 49, Age: 11 y 10 m. If I take a pendulum and push them they move very fast. But if their weight is more they go very near. All the pendulum i.e. 3 pendulum will go near if it is 100 gms. 200 gms. Fig. 29 300 gms. but the least one only will go near. Then I feel that weight of the bob is an important factor.
VIII.	Deepak, I.Q. = 82; Age: 12 y 6 m. Due to the weight of the bob the oscillation is easier because of weight it can move forwarded and backward. We can calculate that the weight of the bob is useful.	Shobhashri, I.Q. = 98, Age: 12 y I take two bobs A and B. The material of the A bob is wood and the material of the bob B is steel. Then I calculate that the volume is same.
IX.	Nil	Gladis, I.Q. = 76, Age: 13 y 6 m. Take two bobs of different weights. And the string of different size. The oscillation made by them also differs because the bobs are of different weights and the straight is of different size.
X.	Shiva Kumar, I.Q. = 75, Age: 14 y 3 m. Iron Wood The weight of the bob is different though the volume is same. 75 gms. 50 gms. Fig. 30	Nil

1 Mark Level Responses		
1	2	3
VI.	Mohan, I.Q. = 120, Age: 9 y 10 m. Take two bobs, one made of iron and the other wood. If time taken for one oscillation is the same it is not an important factor. If the time taken for one oscillation is different I conclude it is an important factor.	Jyothi, I.Q. = 76, Age: 10 y. 2 m Take two bobs of 100 gms. and 50 gms. iron and wood. The time for one oscillation depends upon the following factors :
VII.	Mayan, I.Q. = 83, Age: 11 y 7 m. I shall take three bobs of different wt. One of 100 gms, 200 gms. and 300 gms. and tie it to a string and push. If the bob which is 300 gms. went slowly and bob of 100 gms. went fast then weight of the bob is important factor.	Jayanti, I.Q. = 93, Age: 10 y 11 m. I am going to take 2 bobs A and B of 1000 gms. and 800 gms. I am going to push it with the same force. If the A bob goes far from that of the B bob then I say weight of bob is important. If bob go at the same distance than I suggest that it is important factor.
VIII.	Anil, I.Q. = 99, Age: 12 y 8 m. If the time taken for one oscillation is same when I use 2 bobs of different weights, then I conclude that the weight of bob is not an important factor.	Manisha, I.Q. = 84, Age: 12 y 4 m. Take two wooden and steel bobs which is wooden ball is 300 3 cms. and steel ball is 3 cms. and if the time taken for one oscillation is different then I shall conclude that the weight of the bob is an important factor and if the volume is same then I shall conclude that weight of the bob is not an important factor. All other factors in the experiment should be the same.
IX.	Nil	Nil

1	2	3
V.	Keshava Murti, I.Q. = 85, Age: 13 y 10 m. Take two bobs, one steel and another wood of same volume, so weight varies. If the time for one oscillation is same then it is not an important factor.	Smita, I.Q. = 99, Age: 14 y. Take bobs of different weights, if the time taken for one oscillation is same then it is an important factor. If the time taken is different then it is not an important factor.
	2 Karan Level Responses	
VI.	Prasad, I.Q. = 100, Age: 10 y 6 m. I shall take 2 bobs of different weights and attach to same string and see the time for one oscillation. If it is same, ~~if~~ it is not an important factor. If time is different it is an important factor.	Sagama, I.Q. = 50, 10 y 6 m. Take two bobs of 100 gms. and 50 gms. If the time taken for one oscillation is the same then this factor is not important. If the time taken is different then I conclude that this factor is important.
VII.	Chandra, I.Q. = 31, Age: 11 y 6 m. When two bobs of 50 gms and 60 gms are oscillated by the string and different readings are obtained for one oscilla-tion, it is an important factor.	Mitra, I.Q. = 112, Age: 10 y 10 m. For this I shall take 3 bobs which have different weights e.g. 10 gm. 20 gms. 30 gms. Fig. 31 If the time taken for one oscillation is the same in the three types of bobs then it is not an important factor. But if the time is different then this is considered as an important factor.

1	2	3
VIII.	Santosh, I.Q. = 99, Age: 12 y 9 m. In this experiment I will take a bob of 40 gms. and another bob of 60 gms. and oscillate them. Time for one oscillation is noted and if it is found same, then it is not important. Time is different means it is important.	Anvita, I.Q. = 106, Age: 11 y 11 m. I shall take two bobs of different weights. Then I shall move both the bobs and note the time taken for one oscillation. If the time taken for one oscillation differs then I shall conclude that weight of the bob is not an important factor. If the time taken for an oscillation is same then I shall conclude that weight of the bob is not an important factor.
IX.	Take three bobs of same volume but different material and oscillate them. Note the time for one oscillation. If the time taken for both is different, then it is an important factor.	Hemanth Kumari, I.Q.= 78, Age: 13 y 10 m. Two bobs one steel and other wood, volumes are same and other factors are same. If the time taken for one oscillation are same for both steel and wood then it is not an important factor. If the time taken for one oscillation varies then it is an important factor.
X.	Here I take the same material of the bob, same volumes, same length and material of the string same hook. But I will change the weights of the bob. I will take 3 bobs of different weights (low, high or medium). If the time taken by pendulum for one oscillation in different weights of bob is same then it is not an important factor. But if the time taken by 3 weights of bob of the pendulum for one oscillation varies then I can prove that this factor is important.	Manjula, I.Q. = 89, Age: 14 y. Take the bobs with different weights (same volume). Then see the oscillation of the different bobs. If we see change (difference) in the oscillation, time, then the weight is an important factor. If the time taken is different then it is not an important factor.

3 Marks Level Responses

1	2	3
VI.	Santhosh, I.Q. = 112, Age: 10 y 9 m. I shall take two bobs. One of 100 gms. and other of 50 gms. but same volume (i.e. different material) of the time taken for one oscillation is same, the weight of the bob is not an important factor.	Jayashree, I.Q. = 97, Age: 10 y 6 m. I will take two bobs of one 150 gms. and other 50 gms. and one is iron and another wood. If the time taken for one oscillation is made, it is not an important factor and if the time for one oscillation is not same then it is important.
VII.	Anil, I.Q. = 107, Age: 11 y 2 m. Take two bobs of different weights that is of 5 gms. and other 2 gms. and keep volume same. If the time for one oscillation is different for 5 and 2 gms. bobs then it is an important factor otherwise it is not an important factor.	Harini, I.Q. = 116, Age: 11 y. First I shall take 3 bobs of different wt. i.e. 1 kg., 2 kg., 3 kg., Then I shall fix the bob of 1 kg to a string and note down the time taken for one oscillation. If the time taken by all the 3 bobs for one oscillation is the same, then I shall consider that the weight of the bob is not an important factor. 1 kg. 1 kg. 3 kg. Fig. 32
VIII.	Santosh, I.Q. = 99, Age: 12 y 9 m. Take 3 bobs of different weights and fix it to the string. If the heaviest bob swings more and other bob less then it is an important factor, otherwise it is not an important factor.	Lalitha, I.Q. = 82, Age: 12 y ? m. Take a bob made of iron and another bob made out of wood. Let the other factors remain the same. Now push the bob. Note the time taken for the that if the time varies this factor is important. If it takes the same time this factor is unimportant.

1	2	3
11.	Shiva Prakash, I.Q. = [illegible], Age: 13 y. 11m. Take three simple pendulum which are same in all respects except the weights of the bob. Hence take e.g. bobs of wood, brass and iron. Calculate time taken by the three simple pendulum for one oscillation. If the time taken varies for the three, then it means that weight of the bob is not an important factor. If the time taken is same, it means it is an important factor.	Uma, I.Q. = 75, Age: 13 y 9m. Two bobs one of steel and the other wood are taken of the same size. Thus volume remains same and weights differ. The size of the string is also same. And if there is difference of time for one oscillation we conclude that the weight of the bob is an important factor but if the time taken for one oscillation remains same, we conclude that it is not an important factor.
1.	Chandra, I.Q. 103, Age: 13 y 11 m. Take a bob of 5 cms. diameter and having a weight of 25 gms. and tie it to a thread making it a pendulum. Take another bob of 5 cms. diameter and having a weight of 50 gms. and tie it to a thread making it a pendulum. Now oscillate the pendulum. If the time taken to oscillate differs, then the weight of the bob does not count as a factor.	Sharada, I.Q. = 119, Age: 14 y 5 m. Take two pendulum whose bobs are of different weights. Let all other factors remain constant (same). Now give a slight push to the pendulum. Note down the time taken by the pendulum. For one oscillation. If the time taken by the pendulums for one oscillation is same then the weight of the bob is not an important factor. If the time taken by the pendulum for one oscillation differs then the weight of the bob is an important factor.

Table 7

Sample Responses at Four Levels (0, 1, 2, 3) Grade-wise and Sexwise on the Two Variables of the Ramp Problem

1st Variable - The weight of the Target Sphere

Zero Mark Level Responses

Grade 1	Boy 2	Girl 3
VI.	Ashwini Kumar, I.Q. = 56, Age:10 y 9 m. Take two target spheres and rolling sphere and keep it in middle. If the two spheres travel the same distance, then it is not important factor.	Kamtha, I.Q. = 56, Age: 10 y 5 m. Take two T.S. If we push rough to smooth it will go fast. If we push smooth ball to rough ball it will also go fast and we must push the rolling sphere fast and it will push and the target sphere will go fast.
VII.	Umesh, I.Q. = 84, Age:11 y 2 m. I shall take a target sphere. If the target sphere is heavy it wont go much forward. If it is light it will go to long distance. This shows that the weight of the bob is an important. factor.	Lita, I.Q. = 103, Age: 10 y. If the target sphere has very much weight then it will be hard to climb up the ramp. If the target sphere is of less weight then the target sphere can climb the groove. So my conclusion will be correct.

Fig. 33

1	2	3
VIII.	Prasanna, I.Q. = 82, Age: 12 y 6 m. If we take an iron target sphere of the same size and weight, then I conclude that the weight of the target sphere is not important factor. If I take an iron target sphere of the same size and weight is different then I conclude that the weight of the target sphere is important.	Chandana, I.Q. = 100, Age: 12 y 10 m. I shall take a target sphere and rolling sphere. I will weight it. If it is different, I shall conclude it is an important factor. If it is of same weight, I will conclude that it is not an important factor.
IX.	Shankar, I.Q. = 61, Age: 13 y. 11 m. When two target spheres of different weight are taken, the heavy one moves slowly and the light one moves fast so the weight of T.S. is important.	Bindu, I.Q. = 76, Age: 13 y. 6 m. Two target spheres are taken of two different weights. Then leave it from a starting point. Then we find that time taken for the two target spheres to roll is same then it is not an important factor. If the time taken depends on the weight, that is if the time varies from the rolling of target to the rolling of the 2nd target then we can say that it is an important factor.
X.	Kiran, I.Q. = 75, Age: 14 y. If the weight of the target sphere is more the rolling sphere moves less distance. If the weight of target sphere is less, then the rolling sphere moves more distance.	Nil

1 Mark Level Responses

1	2	3
VI.	Mohan, I.Q. = 120, Age: 9 y 10 m. Take two target spheres of different weights. If the distance travelled is same for both, then the weight of T.S. is not important factor. If the distance travelled for heavy sphere is more, then the weight is important.	[illegible], I.Q. = 56, Age: 10 y. 6 m. Take two T.S. of different weights, if the time is taken same for two to travel then the factor is not important. If the time taken is different to travel then I conclude this factor is important.
VII.	Rajkumar, I.Q. = 85, Age: 11 y. 4 m. One heavy target sphere and one light sphere is made to move up the ramp. Distance travelled shows whether it is important or not.	Augur, I.Q. = 85, Age: 11 y 6 m. 1. I shall take two target spheres, one of weight 300 gms. and one of 700 gms. 2. The other factors shall be the same. 3. The target sphere of weight 300 gms. moves up faster. This factor is very important. 4. The target sphere of weight 700 gms. does not move up faster, this factor is not important. 5. The problem is solved in this way. 300 gms. 700 gms. Fig. 34

1	2	3
VIII.	Yogendra, I.Q. = 88, Age: 12 y 7 m. Take one wood and one iron target sphere and see their movement on the ramp. If they are same or different.	Sabitha, I.Q. = 66, Age: 12 y 4 m. Take two target spheres, one iron and one steel. If the distance of both the target sphere is same (the distance it has rolled). Then it is not an important factor. If it differs then it is an important factor.
IX.	Narasimhan, I.Q. = 94, Age: 13 y 10 m. Take a target sphere which is light and see how far it goes. Take another target sphere which is heavy and again note how far it goes. If the reading same it is not an important factor. If the reading is different, it is an important factor.	Srishree, I.Q. = 86, Age: 13 y. 2 m. If the distance travelled by the target sphere, is same, then the weight of the target sphere is not an important factor. Similarly if the distance travelled by the target sphere is different the weight of the target sphere is important factor.
X.	Madhukar, I.Q. = 85, Age: 14 y 4 m. Let the ramp and other apparatus be the same but take 3 target spheres of different weights. Try rolling the three target spheres at a time. If the three target spheres move with the same speed, then the moving of the target sphere depends on the weight of T.S. If not, moving of the target sphere does not depend on the weight of the target sphere.	Aruna, I.Q. = 89, Age: 14 y 2 m. Take different weights of target sphere. If the time taken is the same, then the weight taken is not an important factor. If the time taken is different then it is an important factor.

2 Marks Level Responses

1	2	3
VI.	Ashithya, I.Q. = 125, Age: 10 y 2 m. Take three T.Ss. of different weights and see distance travelled when rolling sphere hits. Same distances means not important. Different means important.	Jayalakshmi, I.Q. = 105, Age: 9 y 11 m. Take two T.S., one of 100 gms. and one of 10 gms. and keep it on a ramp and push the rolling sphere. If the distance travelled by the target sphere is same then the weight of the target sphere is not important.
VII.	Anup, I.Q. = 116, Age: 11 y 1 m. I take two target spheres of different weights. Say one of them is 100 gms. and the other 200 gms. If the distance travelled by the target sphere is same then it is not an important factor. But if the distances travelled by target spheres is different then it is an important factor.	Nirmala, I.Q. = 49, Age: 11 y 10 m. If I take 2 target spheres and if one is 100 gms. and the other 200 gms. and I push it and if they go the same distances then weight of the target sphere is not important. If they move more or less distance, then weight of the target sphere is important.
VIII.	Srivatsa, I.Q. = 95, Age: 12 y 2 m. If we take an iron target sphere and an wooden target sphere, weight is different from each other. If we roll the rolling spheres, the target sphere moves up the ramp. If the distance travelled by both kinds is the same, then it is not an important factor. If the distance differs then it is an important factor.	Kiran, I.Q. = 91 Age: 12 y 7 m. I shall take two target spheres of different weight. Then I shall take a R.S. and roll it towards the T.S. so that the T.S. shoots up. I shall note the distance travelled by the T.S. is the same in both the cases, then I shall conclude that the weight of the target sphere is not an important factor. If the distances travelled by the T.S. is different, I shall conclude that the weight of the target sphere is an important factor.

1	2	3
IX.	Nagaraj, I.Q. = 103, Age: 13 y 11 m. Take three target spheres of different weights but same volume. If they move at the same speed then it is not an important factor. If it varies then it is an important factor.	Savitha, I.Q. = 84, Age: 13 y. I shall take two target spheres of same volumes and different weight. When the rolling sphere strikes the target sphere and the target sphere moves the same length then it is not an important factor. If it is different then it is important.
X.	Satish, I.Q. = 103, Age: 14 y 1 m. I shall take two target spheres, one of cork and other rubber. They will have same volumes but different weights. When the rolling sphere strikes the target sphere it moves up the ramp. The distance, they both travel is noted. If they are same, it is not an important factor. If it is different, it is an important factor.	Pavana, I.Q. = 103, Age: 14 y. Take target spheres of different weights but same volume and see the time taken. If the time taken varies, it is an important factor. If the time taken is same, then it is not an important factor.

3 Marks Level Responses

1	2	3
VI.	Santhosh, I.Q. = 118, Age: 10 y. 9 m. I will take two T.S. one of 10 gms. and another 15 gms. weight. If the distance moved by T.S. is same then weight of the T.S. is not an important factor. If the list moved different then it is an important factor.	Meena, I.Q. = 100, Age: 10 y. 8 m. Take two T.S. one of 100 gms. and the other of 10 gms. If the distance travelled by T.S. is same in both cases, then it is not an important factor. If the distance travelled is different, for both cases it is an important factor.
VII.	Sriram, I.Q. = 105, Age: 11 y 10 m. Take two ramps and two target spheres which weights 30 gms. and 60 gms. Use same rolling sphere. Roll the rolling sphere. See the distance travelled with scale and if they are same for both the T.S. then it is not important. If the distance is different it is important.	Pushpa, I.Q. = 85, Age: 11 y 10 m. Two target spheres are taken of different weights e.g. 400 gms. and 600 gms. Release the rolling sphere. If the target spheres of 600 gms. goes higher than 400 gms. or T.S. of 400 gms. higher than 600 gms., then it is an important factor. If both the spheres travel same distance it is not important.
VIII.	Arul, I.Q. = 95, Age: 12 y. I shall take two target spheres of different weights. Then I shall release the rolling sphere from one end. If the distance travelled by the T.S. of different weights is noted. If it is different then I shall conclude the factor is important. If the distance travelled by T.S. is same it means, it is not important.	[illegible], I.Q. = 85, Age: # 12 y. When on a ramp a target sphere and a rolling sphere is kept, think target sphere is of iron and when the rolling sphere is rolled on and when it hits the target sphere and the time taken and the distance covered should be noted down and if the target sphere is of steel and when it is rolled down the ramp and the time taken and distance covered is different (from the previous one) then I shall conclude that the weight of the target sphere is an important factor. And if the time taken

1	2	3
		and distance covered is the same in both cases. I shall conclude that the weight of the target sphere is not an important factor. In this experiment all the things should be the same and only the weight of the target sphere should be different.
11.	Ramesh, I.Q. = 89, Age: 13 y 9 m. Take the apparatus as shown in the above figure and let the apparatus be same except target balls. Now take the target balls of three sizes t_1, t_2 and t_3. Now place a target ball at the same graduation in all the three experiments. Let the rolling sphere be released from the same graduation mark from the top. After collision the target ball moves upto certain distance. If the target sphere with least weight ~~sphere~~ moves through greater distance and if the target sphere with highest weight moves up less distance, we can conclude that the moving of the target sphere depends on the weight of the target spheres and hence the moving of the target ball is proportional to its weight. If all the target balls moves through same distances, it means it does not depend on its weight.	Gladis, I.Q. = 70, Age: 13 y 6 m. I shall take two target spheres of same volume and different weight. When the rolling sphere strikes the target sphere and the target sphere moves the same distance, then it is not an important factor. If it is different than it is important.

1	2	3
V.	Sanne Gowda, I.Q. = 93, Age: 14 y. Take a target sphere of weight 50 gms. and take another target sphere of 100 gms. but of same volume and roll the rolling sphere. If the target spheres differ in their movement then the weight of the target sphere is an important factor and if it does not differ then the weight of the target sphere is not considered as an important factor.	Meera, I.Q. = 106, Age : 14 y. Let it be seen that all the factors in this ramp set up be constant, except take the largest sphere of different weights. Let me be a close observant to note down the graduation in the groove scale, when the target spheres of different weights are made to move. If the reading on the groove scale varies. I shall conclude that this factor is important. If the reading on the scale does not differ this factor shall be rejected as an unimportant factor.

2nd Variable - Nature of the Groove

Zero Mark Level Responses

1	2	3
VI.	Narendra, I.Q. = 89, Age: 40 y 11 m. Take two smooth and hard grooves and release the bob. It is an important factor.	Mamtha, I.Q. = 56, Age: 10 y 5 m. The nature of surface of the groove. Take another kind of balls. One is made of cork and another is made of rubber. The rubber ball is pushed and it will go fast. In the middle there is groove. It must push the cork ball it must go fast.

1	2	3
VII.	Vinay, I.Q. = 54, Age: 11 y. I shall take a target sphere in groove which is smooth and which is rough. The target on the smooth are goes forward quickly and target sphere on the rough one go slowly. This sphere that the groove is an important factor.	Shobha, I.Q. = 107, Age: 11 y 2 m. If the groove is smooth, the ball will go very up. If the groove is rough the ball will not go up. If it is in same level then it is not an important factor. If it is in the different level then it is an important factor.
VIII.	Ashok, I.Q. = 95; Age: 12 y 7 m. Suppose an take a smooth groove and a rough groove. If the distance travelled by both is the same, then it not an important factor. If the distance differs from each other that is smooth groove and the rough groove, then it is an important factor.	Leelavathi, I.Q. = 86, Age: 12 y. Take the groove smooth and another rough. The target sphere more on both the grooves. If in the smooth groove the target sphere moves fast, it is an important factor. If the target sphere moves slowly in the rough groove it is not an important factor. From this we conclude the material of the groove varies from that of the ramp. If the distance travelled by the target sphere is same, the nature of the surface of the groove is very important factor.
IX.	Nil	Bindu, I.Q. = 76, Age: 13 y 8 m. If the surface of the groove is soft, the distance by the T.S. varies. It is an important factor. If the distance travelled by the T.S. is the same then it is not an important factor.

1 Mark Level Responses

1	2	3
VI.	Ashwini, I.Q. = 86, Age: 10 y 9 m. Take two ramps of smooth and rough groove. If the time taken is the same it is not an important factor. If the time taken is different it is an important factor.	Padma, I.Q. = 56, Age:10 y 6 m. Take two grooves (ramps) one of smooth and other rough. If the T.S. and R.S. is reaching some times. This factor is not important. If for both the grooves different time travel then I conclude this factor is important.
VII.	Anita, I.Q. = 80, Age: 11 y 7 m. I take two grooves which is different in nature. If the target sphere goes different on groove then it is an important factor. If the distance travelled is the same it is not an important factor.	Jayanti, I.Q. = 93, Age: 10 y 11 m. I take 2 grooves one rough the other smooth. If the distance travelled by the target sphere is the same then it is not an important factor. But if the distance travelled by the target sphere is different then it is an important factor.
VIII.	Suresh, I.Q. = 74, Age: 12 y 10 m. Take two ramps of surfaces smooth and rough. When you see that the target sphere move slow in the rough groove and fast in smooth groove it is an important factor.	Kala, I.Q. = 91, Age: 12 y 6 m. Take 2 ramps with same shape and same spheres but one groove rough and other smooth. Make the rolling sphere strike. The distance travelled by the sphere smooth groove is more than the rough groove. If the distance travelled by the smooth is not more than it not an important factor.

1	2	3
IV.	Jaya Prakash, I.Q. = 73, Age: 13 y 1 m. I shall take two grooves of different nature (smooth and rough). If the target sphere move freely in both the cases I shall conclude that it is not an important factor. If the target sphere movement varies I shall conclude that it is an important factor.	Nandini, I.Q. = 81, Age: 13 y. Take two ramps one with soft groove, and the rough groove. If the time taken for the moving of the target sphere is same then the nature of the groove is not an important factor. If the time taken for the moving of the target sphere is different then the nature of the groove is not an important factor.
V.	Nil	Pavana, I.Q. = 103, Age: 14 y. In the groove of different surfaces and nature see the target sphere moving in the groove. If the time taken is the same it is not an important factor. If the time taken is different it is an important factor.

2 Mark Level Responses

1	2	3
VI.	Kamalesh, I.Q. = 89, Age: 10 y 9 m. When two different surfaces of grooves are taken and if the T.S. moves same speed in back then it not important. If the distance varies it is important.	Meera, I.Q. = 100, Age: 10 y 8 m. Take ramps with smooth groove and rough groove. If the distance travelled by T.S. is same then it is not an important factor. But if the distance travelled by target sphere is different then it is an important factor.

1	2	3
VII.	Anup Lakhani, I.Q.= 116, Age:11 y 1 m. I take 2 (ramps) grooves, one rough, and the other smooth. If the distance travelled by the target sphere is the same then it is not an important factor. But if the distances travelled, by target sphere is different then it is an important factor.	Seema, I.Q. = 89, Age: 11 y. I shall take 2 ramps i.e. one which is smooth and one which is rough and keep two target spheres in each of the groove of the ramp. Then take a rolling sphere and push it and if the target sphere which is in the smooth ramp goes far than in rough ramp, then the nature of the surface of the groove is an important factor and if the distance travelled by the target sphere is same then it is not an important factor.
VIII.	Prasanna, I.Q. = 82, Age: 12 y 8 m. If I take the grooves of different a kind (smooth surface and rough surface) and the distance travelled by the T.sphere is same for both, then I conclude that the nature of the surface of the groove is not important. If the distance travelled by T.sphere is different it is important.	Kala, I.Q. = 100, Age: 12 y 10 m. I shall take a smooth groove and a rough groove and I shall see the distance of the target sphere travelled in both. If the distance travelled by target sphere is same. I shall conclude it is not an important factor. If the distance travelled is different then I shall conclude it is an important factor.
IX.	Manjunatha, I.Q. = 73, Age: 14 y. Take two grooves one smooth and one rough. If the target sphere move at the same time in both the grooves it is not an important factor. If the time varies then it is an important factor.	Padmavathi, I.Q. = 96, Age: 13 y 1 m. Take two grooves. Let one be smooth and the other rough. Let all the factors remain same. If the distance travelled by the target sphere is same then it is not an important factor.

1	2	3
A.	Take two ramps, whose grooves are of different nature and then see the movement of the target sphere. If there is no change, then it is not an important, if there is change, it is an important factor.	Meera, I.Q. = 106, Age: 14 y. In the groove of different surface and nature (rough and smooth) see the target sphere moving in the groove. If the time taken is same it is not an important factor. If time taken varies it is an important factor, otherwise not.
	3 Mark Level Responses	
VI.	Mohan, I.Q. = 120, Age: 9 y Take two ramps one of rough groove and one of smooth groove. If the target sphere takes the same time to reach a certain distances than the nature of the groove is not an important factor. If target sphere reaches at different times then the nature of the groove is an important.	Latha, I.Q. = 98, Age: 9 y 11 m. I shall take two ramps groove of one is small and another rough. If the distance travelled by T.S. is the same then the nature of the surface of the groove is not an important. If the distance travelled by target sphere is different then the nature of the sphere of the groove is important.
VII.	Kumaran, I.Q. = 116, Age: 11 y I will take two ramps. The target spheres and rolling spheres of both the ramps shall be of the same weight and volume. But I shall make one groove to be very smooth and the other groove is to be very rough. I shall strike both the target spheres with the rolling spheres. If the target sphere on the smooth groove and the target sphere on the rough groove move up the same level then I shall conclude the nature of the groove as an important factor.	Harini, I.Q. = 116, Age: 11 y First I shall take two ramps of different (nature of the surface of the groove). Example rough and smooth. Then I shall keep a target sphere and a rolling sphere in the smooth one. Then I shall release the rolling sphere. Then I shall note down the distance the target sphere travels. Then I shall keep them in a groove of rough surface then release the rolling sphere. Then I shall note down the distance the target sphere, travels. If

	1	2	3
			both the distances are the same then I shall not consider the nature of the surface of the groove as an important factor.
VIII.	Arjun, I.Q. = 99, Age: 12 y 4 m. Take a ramp with a smooth groove and another with a rough groove. If the target sphere travel the same distance, it is not an important factor. If the distance travelled is different it is an important factor.		Airan, I.Q. = 91, Age: 1[illegible] y 7 m. I shall take two ramps. One ramp with a smooth surface and the other ramp with a rough surface. Then I shall release the R.S. and T.S. move upwards. I shall note the distance travelled by the T.S. If the distance travelled by T.S. in both the cases are same. I shall conclude that it is not an important factor. If the distance travelled differs then I shall conclude the nature of the surface of the groove is an important factor.
IX.	Shiva Prakash, I.Q. = 89, Age: 13 y 11m. Take two ramps, one with a rough groove and the other with a smooth groove. Keep in all the other factors constant. Roll the rolling sphere and observe how the target sphere moves. If it moves with different speed in the two grooves, then the nature of the surface of the groove is an important factor.		Kokila, I.Q. = 89, Age: 13 y 3 m. Take two grooves of same size length etc., but different surfaces, let first grooves be smooth and the second groove be rough. If the distance moved by the target sphere is same, then the surface of the groove is not an important factor. If the distances moved by the target sphere is different, then the surface of the groove is an important factor.

1	2	3
A.	Mohan, I.Q. = 94, Age: 14 y 5 m. I take 1 ramp with smooth groove and 1 ramp with rough groove in all other respects they are same. If the distance travelled by the T.S. is same with different groove then it is not an important factor. If it differs it is an important factor.	Anupama, I.Q. = 106, Age: 14 y 4 m. Take 2 ramps one with a rough groove and the other with a smooth groove keeping the other factors constant (same). Roll the rolling sphere and observe now the target sphere. If the moving of T.S. gives different reading on the groove scale, then this factor can be considered very important. If the moving of the target sphere is with the same speed in both the grooves then this factor is concluded not important.

Table 5

Sample Responses at Three Levels (0, 1 and 2) for the Three Questions of the Worms Problem

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Q.1 What do you conclude from the diagrams (1) and (3)?

0 - mark level response :
Sreedhar, I.Q. = 88, Age: 10 y 2 m.
Only dryness is important

1 - Mark level response :
Giri, I.Q. = 66, Age: 11 y 4 m.
Light and dryness are equally important.

2 - Mark level response :
Anupama, I.Q. = 106, Age: 14 y 4 m.
Light is important.

Q.2 What do you conclude from the diagrams (2) and (4)?

0 - Mark level response :
Suresh, I.Q. = 74, Age: 12 y 10 m.
Moisture (Wet) is important.

1 - Mark level response :
Kumar, I.Q. = 101, Age: 11 y 11 m.
Only dryness is important.

2 - Marks level response :
Prasanna, I.Q. = 110, Age: 13 y 11 m.
Light and dryness are equally important.

Q.3 Is any other experiment necessary? If yes, suggest the experiment with diagram.
0 - Mark level response :
Kavitha, I.Q. = 108, Age: 11 y 11 m.
No other experiment is necessary.

1 - Mark level response :
Sujay, I.Q. = 104, Age: 11 y 5 m.

Fig. 35

2 - Marks level response :
(1) Kumaran, I.Q. = 116, Age: 11 y.

Fig. 36

(ii) Koustubha, I.Q. = 102, Age: 13 y 8 m.

Fig. 37

(iii) Poornima, I.Q. = 104, Age: 13 y.

Fig. 38

(iv) Beena, I.Q. = 89, Age: 11 y.

Fig. 39

Take a box with 20 worms and place it in the centre of the glass box. Sprinkle water on the bits of paper in one half of the box to make it wet. Let the source of light be from the top of the box between the wet and dry area.

(v) Sujatha, I.Q. = 119, Age: 14 y 6 m.

Fig. 40

The above mentioned responses, largely speaking, confirm the tentative conclusion which has received exhaustive treatment in The Growth of Logical Thinking in Science During Adolescence by Vaidya (1979). Adolescent pupils are in a position to set up hypotheses very markedly the way they see the problem. They sometimes, frequently, specially at lower ages, bring in lot of arbitrary responses which can be suitably classified: making comments, giving values to the variables, suggesting ways out of the problem, demanding information, trying to work hard on irrelevant responses, repeating and reproducing parts of the problem, etc. Interestingly enough, these arbitrary errors disappear at the higher age levels. They appear because of the failure to understand the basic requirement of the problem. Or while trying hard to carry out the various experiments, they arise due to the failure to separate out the variables distinctly. Secondly, ability to test hypotheses appears to develop gradually rather than as a single shot on incidence of adolescence. Thirdly, whereas there is variety in responses evoked by the various problems at the zero mark level responses, the same tends to narrow down when higher level responses are elicited or emitted. At the highest level, one sees very closely resembling responses evoked by the British, Swiss, American and Indian children. The striking feature of this developing view is, that logical thinking especially the way it develops really tends to become universal, a basic tenet of Piagetian psychology. One therefore tends to see some sort of parallelism among the various sample

responses of other specific considerations of variety in specific contexts are ignored. To illustrate :

In this study, four problems were used for investigating the ability to test hypotheses through exclusion of variables or controlled experimentation. These were :

1. The flow of liquid through a tube problem
2. The simple pendulum problem
3. The ramp problem
4. The worms problem.

The first problem was used by Vaidya and by the author in this study for investigating adolescent thought. The second problem was used by Piaget and Vaidya on Swiss Children; and British and Indian children respectively. The remaining two problems were designed and used by Karplus, Lawson and Renner. They are being used on Indian children for the first time as far as the knowledge of the author goes, in this country. The chief interest in making this illustration is, to see the pattern of responses by using the scoring key developed empirically in this study and to discern any parallelism if it does exist at all. Below are presented some sample responses to exemplify the tentative conclusions reached above.

Table 9

Sample Responses of the Flow of Liquid Through a Tube Problem of Another Study

Sr. No.	Author and Year	Sample Responses
1.	Vaidya N. (1979)	B-44, I... 77, Grade VIII. Zero Mark The tube has a hole here and also there. Water passes through these two holes (wants to say that the tube is hollow). First of all, I took a beaker and then two glasses. I also took two tubes. I fixed one of the two in the beaker, water came out. I collected it in the glass (Why the second glass?). Now will I, otherwise, pour water into the beaker? (Space is still available for writing. He must fill it in). The drying up of the hanky depends upon several factors. Take hankies of the same colour. Their lengths, widths and thickness also the same. Take any utensil and pour water into it. Wet these hankies. Drench the water out. Then spread out the hankies in the sun. They will dry up soon. What are the factors? 1. To drench them 2. To spread in the sun. 3. To place them in front of the fire. 4. Do not forget about the thickness of the hanky. It is very important.

S. No.	Author and Year	Sample Responses
		(But you are not supposed to solve this problem). Sir, it is a similar problem. In place of hankies, there are glass tubes.
2.		B.58. I.Q. 115, Grade VIII. 5 Marks (Looks thoughtfully at the experiment set up). The says : Water is coming out of the larger beaker into the small beaker. You know that water always flows from higher level to another level. Hesitates for some time and then says : Length is important. If no length, no water will be collected. Laughs because the problem goes! I mean length can change. No! I mean hole. It can be small, medium and big. If the hole is large, water level in the larger beaker will fall down quickly. I can show this to you. I will proceed as follows : Take two tubes, one small and other large. (Out of these tubes, which one will you pick up?) I will pick up that one whose holes are the same.

S. No.	Author and Year	Sample Responses
		Takes the two tubes (Yes, you are correct). If I have the large tube and fix it there, water will come a bit soon. There is going to be small difference in time. So smaller the tube, sooner the water will come out. (Now thinks! Then says that our problem is to find out whether length plays an important part in the amount of water collected). Give me some time. Asks : what is this? (This is a watch. I have told you earlier). I am a fool because the water has to come out of the two glass tubes. Now I think I can solve the problem like this. Fix the tube as usual. Collect water for five minutes. Now change the tube. It should be either smaller or longer. Then collect water again for five minutes. Now I can make the judgement like this. If longer tube gives more water in five minutes, then length is an important factor. If the shorter one gives more water to the collecting beaker, then I can say that length is an important factor. If amount is the same, then length has nothing to do here. Similarly, he gives experiments isolating the factor of hole. Now he comes to the end of his wits. If I increase the size of the hole, the level of water falls down immediately. If I take the other tube (with a smaller hole, it takes time for

S. No.	Author and Year	Sample Responses
		the water to go. Level of water falls down slowly and slowly. (Level) water fell in the other experiments as well (While isolating the factors of length and hole). Thinks. Plays with the pencil. I think this factor has nothing to do because water falls down anyway.

Table 10

Sample Responses of The Simple Pendulum Problem of Other Studies

S. No.	Author and Year	Sample Responses
1.	Piaget, J. (1958)	PER (10.7): Failure to separate variables. He varies simultaneously the weight and the impetus; then the weight, the impetus, the weight, and the elevation, etc. and first concludes: "It's by changing the weight and the push, certainly not the string" - How do you know that the string has nothing to do with it? - "Because it's the same string". He has not varied its length in the last several trials, previously he had varied it simultaneously with the impetus, thus complicating the account of the experiment. But does the rate to speed change?

S. No.	Author and Year	Sample Responses
		"That depends, sometimes it's the same... Yes, not much... It also depends on the height that you put it at (the string). When you let go low down, there isn't much speed". He then draws the conclusion that all four factors operate: "It's in changing the weight, the push etc. With the short string, it goes faster", but also "by changing the weight, by giving a stronger push", and "for height, you can put it higher or lower" - How can you prove that? "You have to try to give it a push, to lower or raise the string, to change the height and the weight." (He wants to vary all factors simultaneously).
2.		JOT (12.7): Possible but not spontaneous separation of variables. He believes that "You have to pull down (lengthen) the string". He suspends 20 grams and varies the length. "It goes more slowly when you lower (lengthen) the string and faster when it's high up" - That's all? - "May be the weight does something". But to verify this, he takes 100 gms. and lengthens and shortens the string, then 50 grams, lengthening and shortening the string again: "Yes, it goes faster

S. No.	Author and Year	Sample Responses
		high up (= when the string is short); it's the string." In other words, he varies the string instead of the weight. Then he changes the weight while again varying the string in the same way. This process makes it possible to draw a conclusion, providing that the respective frequencies are remembered from one situation to another, but it complicates the matter uselessly. When the subject is asked to give proof of the influence of length, he is satisfied with a pure deduction: "When the string is long, it takes more time to go from one end to the other. When it is short, it takes less time."
3.		EMA (15.1): Succeeds in "the separation of variables and the exclusion of inoperant links." After having selected 100 grams with a long string and a medium length string, then 20 grams with a long and a short string, and finally 200 grams with a long and a short concludes : "It's the length of the string that makes it go faster or slower; the weight doesn't play any role. She discounts likewise the height of the drop and the force of her push.

S. No.	Author and Year	Sample Responses
II.	Vaidya, N. (1964)	
1.		Peter White : The extraneous and arbitrary considerations brought into the solution of the problem. "I guess that the weight of the bob is 4 oz. Volume is 1/2" and length of the sueing is 2 ft". He swings the pendulum again and again.
2.		Linda: Grasps the essence of the problem. Get the bob on the length of the string. Count swings. Increase weight of bob, but keep both length of string and position of swing same. Count swings. Decrease weight of the bob; keep length of the string and position of swing same. Count swings. If swings in one minute are same, weight of balls does not matter. If swings in one minute are different, weight of bob matters. Keeping same weight of bob, and length of string and swinging position - first increase then decrease volume of bob. If number of swings are same, it doesn't matter about volume of bob. If different, volume of bob matters."

Table 11

Sample Responses of the Ramp Problem of Another Study

No.	Author and Year	Sample Responses
1.	Karplus (1975)	0 point - any starting position lacking an explanation or accompanied by an "explanation" that describes the experimental set-up, what the subject wishes to find out, or the phenomenon that will occur. e.g. Well it seems that if you start it (spheres, high they'll both got a lot of speed which would be better.
2.		1 point - equal starting positions accompanied by an "explanation" that ascribes importance, value, or usefulness to this equality. e.g. Start them at the same place and give them the same speed, then measure how far the target goes up the other side.
3.		2 points - equal starting position accompanied by an "explanation" stating the necessity of choosing this equality and possibly mentioning the principle that only one condition should be varied at one time. e.g. The main reason of this experiment is the weight difference, so you would have to keep all other factors the same.

Table 12

Sample Responses of the Worms Problem of Other Studies

No.	Author and Year	Sample Responses
I.	Lawson (1974)	
1.		"A" Level response Student A-1 Jerry - (Age/ "no definite pattern was followed by the mealworms." "B" Level response. Student B-5. Marie (Age - 16). The mean worms in all cases respond to light. However in box 3, the division is about 1:1. This shows that the worms are attracted to the light but not like the situations where the dry area was next to light. When there is no choice between wet and dry such as in case IV, the worms turn to the light. Note: We must also test a box like this with no light to further verify the effect of moisture. wet dry Fig. 41
II.	Renner (1977)	
1.		No answer; no attempt. This includes statements such as, "I don't know what to do", "I don't care", or no statement at all (blank paper). Only one out of the 200 responses was clarified in this category.

S. No.	Author and Year	Sample Responses
2.		The response uses a wrong hypothesis or is irrelevant. Responses in this category are those in which the answer does not deal with the problem, although something is written down. a. In one type of response, representative of possibly the lowest level of intellectual development, the student attempts to address the question, yet his answer makes no sense to the evaluator and is very illogical. b. Another type of response which can be expected which is included in this category is the "smart aleck" answer. Nothing is learned about the students intellectual level from this type of answer, but it can be speculated that the student feels uncomfortable with the problem and therefore is most likely concrete. c. In another type of response the student talks about subjects relating indirectly to the problem, yet does not touch the answer. This type of response is possibly the highest quality of response in the irrelevance category. e.g. "May be you could see if the difference in the weather out side would have to do anything with it."

L. No.	Author and Year	Sample Responses
3.		The student restates the problem experiment by experiment. The student may simply describe what he sees in the pictures of the worms. The student may have other comments referring to what the worms like and dislike, but the essence of the answer is simply description. The response does not include a generality that the worms like light or darkness but simply comments on what is seen from diagram to diagram.
4.		The response includes an hypothesis about what the worms like (such as light), centering on a certain aspect of the problem. These students see light, or wetness, or dryness, or darkness, as the only important variable in the problem. We attribute these answers to centering. e.g. whether it be dry or wet they're attracted to the light.
5.		The student attributes situations in the given experiment to light and dryness plus incorrectly controlled experiments or no additional experiments. It is necessary for the student to recognize the importance of the diagram labeled "Number 2" in the incident to reach this category. The

No.	Author and Year	Sample Responses
		student realize that light and dryness are equally favourable to the worms. In this category the answer need not include an attempt at a controlled experiment, but if attempted it will be wrong. e.g. The information from the diagrams says the worms prefer light dry places."
6.		The answer centers on light plus a controlled experiment. Even if a student centers on only one variable in the problem; if he sets up a controlled experiment he belongs in this category. An experiment stating merely "I removed the light is not sufficient because the grader would have to supply a controlled situation not necessarily implied by the student. e.g. To test their reaction to just wetness or dryness, it would be necessary to prepare a condition of one side wet and one side dry without the light factor.
7.		The student attributes situations in the given experiment to light and dryness plus correctly controlled additional experiment. e.g. To test their reactions she could put a box with a dry and wet side where light strikes both evenly and place another identical box where there is no light.

It is now discernible that adolescent thought is not, strictly speaking, fully formal. In other words, depending upon the nature of the problem and the context in which it is presented, it is a mixture of concrete and formal thought. All researches on adolescent thought are pointing towards this conclusion. This point of view is also supported by the sample responses of other workers which have been just already described. Due to the differing aims and objectives, modes of administration and the pupils' samples, drawn for the various studies, it is difficult to make comparisons. But still, certain trends in responses can be pointed out which can be further subjected to additional experimentation. If sample responses of other studies are read and analysed along with the sample responses obtained in this study, the following conclusion is warranted : A given problem or part of the problem is solved over a wide i.e. range not only within individual grades but also across the grades as well. This view is confirmed by the zero mark level responses on various problems by using the scoring key developed empirically. As additional hypothesis, it is further suggested that there is minimum mental age below which a problem involving formal reasoning cannot be solved. However, there is bound to remain a gap in ages between the experimental solution and the formal solution (see Vaidya, 1968).

Category 3

Permutations and Combinations

In this category as already referred to, two problems were included, which in a way reflected the scheme of combinatorial grouping as their role was regarded limited. With special reference to the present study under investigation, it was decided to classify these two problems under the category of permutations and combinations. This looseness in categorisation was justified because according to Piaget and Inhelder (1958) :

> The formation of propositional logic which itself marks the appearance of formal thought depends upon the establishment of combinatorial system... The structured whole depends on this combinatorial which is manifested in the subjects potential ability to link a set of base associations or correspondence with each other in all possible ways to draw from them the relationship of implication, disjunction, exclusion.

Within the individual contexts of these two problems, the pupils are free to shift from item to item in any way they liked for providing a series of answers. Their number being 24 and 27 respectively. When scored, the highest number became the maximum score for each of the problem. Both of them aimed at investigating the extent to which the adolescent pupils could exhaust all the possible combinations. As phrased, the

digital problem is more narrowly conceived than the Magic Seed problem. Whereas, responses repeated were not scored, they were however counted because they in a way, reflected resting points, on the way, while trying to exhaust all the possible combinations.

Now consider the statement of the two problems as administered to the pupils.

DIGITAL PROBLEM

You are given four digits 6, 7, 8, and 9. Form as many digits or figures as you can by using all these digits in any way you like.

1.	11.
2.	12.
3.	13.
4.	14.
5.	15.
6.	16.
7.	17.
8.	18.
9.	19.
10.	20.

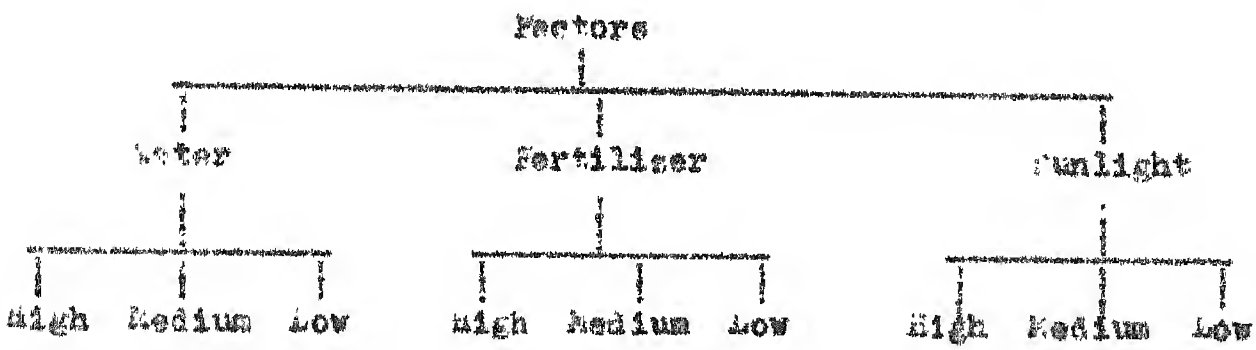
Please continue

THE MAGIC PLANT PROBLEM

A farmer had some magic seeds. He did not know how to grow them into healthy plants. The only thing he knew was that their growth depended upon the following three factors :

1. Water
2. Fertilizer
3. Sunlight

His problem was to know the right amount of each of the three factors mentioned above, to be provided to seeds to make them grow into healthy plants. So, he considered giving the above factors at three levels (amounts) as follows :



He then bought several earthen pots with soil in them and sowed a seed in each one of them and designed several experiments to find solution to his problem. Consider his first experiment.

He sowed a seed in the first pot. He put a lot (High amount) of Fertilizer in it. He also gave plenty (High amount) of water and kept the pot in direct (High) Sunlight.

Your job is to plan as many experiments as you can possibly think of. Please see that no factor or part of the factor is missed by you.

In the table given below, the first experiment is done (entered) for you. Now continue to write the other possible experiments :

Pot No.	Experiment No.	Water	Fertilizer	Sunlight
1.	1.	High	High	High
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Please continue

The data is as presented below :

Table 13

Means and Standard Deviations Grade-wise as well as Sex-wise for the Two Problems of Permutations and Combinations

S. No.	Problem	Sex	GRADES									
			VI		VII		VIII		IX		X	
			Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1.	Digital Problem	B	15.20	3.019	18.90	3.291	19.25	2.653	18.55	5.817	19.15	3.643
		G	15.30	2.430	18.60	3.899	18.50	3.591	19.85	3.660	19.80	3.062
		B+G	15.25	2.706	18.75	3.564	18.87	3.139	19.20	4.842	19.47	3.419
2.	The magic seeds Problem	B	15.05	2.874	19.55	4.379	20.20	3.968	9.75	8.175	20.20	4.175
		G	13.40	7.185	14.30	6.791	18.10	3.553	21.20	2.016	21.90	2.751
		B+G	14.22	5.465	16.92	6.451	19.15	3.667	15.47	6.255	21.05	3.595

Table 14

Mean of Repetitions of the Two Problems of Permutation and Combinations

S. No.	Problem	Sex	GRADE				
			VI	VII	VIII	IX	X
1.	Digital Problem	B	3.35	3.00	3.00	1.65	3.30
		G	3.70	4.70	3.60	1.70	1.55
		B+G	3.52	3.85	3.30	1.67	2.42
2.	The Magic Seed Problem	B	11.05	3.0	4.0	2.0	5.0
		G	9.1	4.4	6.7	4.2	1.2
		B+G	9.57	4.1	5.35	3.1	3.1

Interpretations from the Tables

These two problems being of side interest, the main findings on these two problems indicated :

1. The mean performance on these problems with few fluctuations here and there, except a major fluctuation in grade IX in magic seed problem, increases with grade and indirectly with age as the grade was controlled.

2. As expected, the mean value of resting points decreases with increasing grades with few fluctuations here and there. This repetitive thought, however, is avoidable. If it is accepted that the adolescent pupils do come back to the same step while going ahead in problem solving and this thought in clear cut solutions has no business to appear, it then appears to suffer hump which has received attention in the seventh chapter.

3. Regarding the variability of the group on this category comprising two problems, the performance of the group is, firmly speaking, heterogenous.

4. Boys and girls appear to perform more or less equally as judged by the means alone.

5. According to the Genevans, adolescent pupils are in a position to exhaust all the possible combinations. This however has not taken place as judged by the means as well as the maximum score.

6. If however, criterion is fixed at exhausting two thirds of the combinations the pupils of grades VII to X with little fluctuations here and there, have been able to achieve this criterion. It is just possible the boys of grade IX pupils did not put in the sustained effort, this being the major limitation of the questionnaire approach while investigating Piaget type tasks because, the difference in means between boys and girls on the magic seed problem is (21.20 - 9.75) = 11.45, a large difference otherwise difficult to explain.

7. Pupils have found certain combinations very very difficult to utilize. It is also true that they will miss certain combinations because, theoretically speaking, the total number of combinations maximally are 24 and 27 respectively. Our interest however is, which combination were missed by most of the pupils. The data when analysed showed that the following combinations were very difficult to visualise: 7696, 7968, 8679, 9687, 8796, 9867, 7869, 8697, 9786 and 8976 and the percentage of pupils who missed, these combinations were 34%, 34%, 32.5%, 32%, 31.5%, 31.5%, 28%, 28%, 27.5% and 27% respectively.

8. Similarly, the combinations missed when, the main three variables (water, fertilizer and sunlight)

each at three amounts (high (H), medium (M) and low (L)) were to be combined, were as follows : [illegible] and [illegible]. These were missed by 61.5 per cent, 57 per cent, 56 per cent, 53.5 per cent, 50.5 per cent, 50 per cent, 48.5 per cent, 48.5 per cent, 47.5 per cent and 46 per cent of the pupils respectively.

9. So, the main finding on this loosely defined scheme of thought is that the thinking of pupils of grade VI has not acquired a combinatorial character where their average age is 10 years 3 months. It is therefore hypothesized that the grade has not really advanced the development of combinatorial thought especially when pupils of lower ages are admitted to school.

Category 4

Problem Sensitivity

This category as already referred to, includes only only problem which relates to the formulation of as many questions as possible whose answers pupils do not know. This category was included because it reflected, in our view a type of reasoning which really probed the problem solving situation at depth, to each according to his whim. Not long ago, John Holt remarked :

> We encourage children to act stupidly, not only by scoring and confusing them but by boring them, by filling up their days with dull, repetitive tasks that make little or no claim on their attention or demands on their intelligence.

He has also pointed out that largely speaking, the success of the school is seen in direct proportion to the type pupils who are engaged on tasks characterized by unimaginativeness and mechanicality. As a consequence of this firm tradition, they hardly make use of their 'talents and tools' because before long they are deeply settled in a nut of unintelligent behaviour from which most of them could not escape even if they so wished". Short of creativity variables, that is, fluency and flexibility, the problem under study attempts to explore the extent of the development of the ability to formulate probing questions around an item of common interest.

here, the item being Cycle, known to every pupil, which in one way or other is going to attract a basic characteristic of formal thought. Secondly, taking an over all view, what questions (both accepted and rejected) are asked by the adolescent pupils.

Now consider the statement of the problem as administered to the pupils.

FORMULATING QUESTIONS PROBLEM

Frame as many questions as you can on CYCLE whose answers you do not know. In other words, if you know the answer to the question that comes to your mind, please do not write it down. Now start writing those questions only, whose answers you do not know.

Scoring

It was an open ended question. Any acceptable response carried one mark each as was done in stating of hypotheses. Only those questions whose answers were too obvious were rejected straight away.

The data is as presented below :

Table 15

Means and Standard Deviations Grade-wise and as well as Sex-wise for Formulating Questions Problem

Problem	Sex	Grades									
		VI		VII		VIII		IX		X	
		Mean	[illegible]	Mean	[illegible]	Mean	[illegible]	Mean	[illegible]	Mean	[illegible]
Formulating	M	6.25	4.529	6.30	3.496	10.52	7.376	4.35	7.293	16.30	11.131
	G	5.25	3.024	7.55	4.628	6.60	5.093	7.15	4.095	6.60	2.127
	M+G	5.75	[illegible]	6.92	4.097	8.77	6.713	5.75	6.007	12.45	[illegible]

Interpretation

1. Ability to formulate problems with minor fluctuations increases with grade and indirectly with chronological age, as grade was controlled.

2. Regarding the variability of the group, it is maintained heterogenously across the grades.

3. It is difficult to comment on the quality of questions as judged by the statement of acceptable questions themselves. The following types of questions appear to have been asked.

Why,
What,
How,
Who, and
When

4. Some questions appeared which were too obvious as well as meaningless. It appears that there are adolescent pupils who do not reflect on their responses, a second time. Had they done so, the following would not have appeared. That is, they were not scored.

1. What are the 4 equal parts of the cycle?

2. What is the use of a cycle?

3. How does one ride a cycle?

4. How many types are there in a cycle?

5. How many cycles do you have in your house?

6. How many wheels does a cycle have?

7. Why are you going on the cycle?

8. In a car, many people can sit, but not in a cycle - why?

9. My Daddy can buy a car, why can't he buy a cycle for me?

10. Which cycle do you like most?

5. As judged by the grade means alone, boys ask more questions than girls from grades VI-VIII. In grade IX, the position is just reversed which in turn is again reversed in grade X.

6. The following is a list of accepted questions which appear to have attracted as many as 5 categories. The list of some accepted questions is given below :

(i) Why can't a cycle be reversed like a car?

(ii) Why do the cycle wheels have air-filled tyres and not those of hard rubber?

(iii) Why is the break connected to the handle?

(iv) Why is it hard to pedal up a steep road,

(v) Why does the cycle skid on a wet road?

(vi) Why is the handle almost at the level of the seat?

(vii) Why does the cycle have narrow wheels unlike those of the car?

(viii) Why can't we drive a cycle like a car with a steering wheel?

(ix) Why is the handle bent?

(x) Why does the pedal rotate?

(xi) Why do people apply only the back-wheel brake and not both?

(xii) Why does the chain move only in one direction?

(xiii) Why does a gents cycle have a rod (bar)?

(xiv) Why can't the cycle go on water or air?

(xv) How many spokes are there in a cycle and why is it present?

(xvi) How does the cycle chain break off?

(xvii) How is a cycle different from a scooter?

(xviii) How much does a cycle weigh?

(xix) How long-lasting is an ordinary cycle?

(xx) How is a race-cycle different from an ordinary cycle?

(xxi) How many nuts and screws are there in a cycle?

(xxii) How many cycles are manufactured in India everyday?

(xxiii) How many cycle companies are there in India?

(xxiv) How many ball-bearings does a cycle have?

(xxv) What is the cost of a good cycle?

(xxvi) What type of iron is used for manufacturing the cycle?

(xxvii) What is the length of a cycle chain?

(xxviii) Who invented the cycle?

(xxix) Who rode on the cycle first?

(xxx) Was the idea of constructing the cycle of one man or a group of men?

(xxxi) When was the cycle invented?

(xxxii) When was the dynamo first attached to the cycle?

In short, they posed about a hundred acceptable questions which really tried to puzzle pupils. It appears that the answers to these questions are not

available in their text books, there being few supplementary texts answering these quests. So, the educational value of these questions for day to day classroom teaching cannot be denied. If such questions are collected on other items drawn from the significant areas of human living, they will definitely contribute substantially to the development of environmental education - a scientific slogan of the mid-seventies.

Category 5

Grasping the Essence of the Problem

It is said that a statement is true under certain conditions. When this statement is applied to problem solving, it means that any problem is solved successfully in its context. To put in other words, if the Piagetian view on stage concept is accepted, adolescent pupils should be first in a position to grasp the essence of the problem rather than answering it mechanically. Their thinking should be dominated more by the possibilities of the solution rather than the abject physical statements of the problem. Out of these possibilities, if pupils consult their individual experiences, they should be in a position to make the correct answer or the choice out of the many choices that appear to be available to them. Alternatively, sharing of course the same view, they should desist from answering the problems mechanically. This category comprises 6 funny test items which really go a long way in inviting intentionally wrong answers. The importance of such questions was emphasized by Koffka, a well known Gestalt psychologist, a suggestion which was used by Vaidya and Sandhu in this country. This problem as presented to the pupils is now reproduced below. Scoring is also shown against each item. The item at serial number one carries 2 marks. So, the maximum possible score on this problem is 7.

Table 16

Scoring Key for the Six Items of Questions Inviting Wrong Answers Problem

Q. No.	Question	Right Answer	Wrong Answer	Score
Q.1	A blind man with one eye can see upto a distance of 100 ft. How far can he see with two eyes?	0 ft		2
		100 ft		1
			200 ft	0
Q.2	A cow is standing beside a tree. A rope or cord of 1 metre is tied around her neck. Tell how far from the tree she can go for eating grass.	Can go any where		1
			Any other answer	0
Q.3	Suppose a donkey has two horns. How many horns in all have eight donkeys?	If-then statement		1
			No horns	0
Q.4	A stick is 10 inches long. It is cut an inch per minute. How much time will it take for it to be cut into 1 inch pieces?	9 minutes		1
			10 minutes or any other answer	0
Q.5	How many corners of the handkerchief are left if you cut off one of its corners with the help of a pair of scissiors?	5 corners		1
			Any other answer	0
Q.6	Suppose some ducks are swimming under a bridge in a single line. Two ducks in front, two in the middle and two behind. How many ducks ~~ma~~ are there in all? The number of ducks should be as small as possible, that is, the smallest.	4		1
			Any other answer	0

On reading the items it is apparent that they cannot be answered by ignoring their individual contexts. In the first item, there is an inherent defect. In the second item, the cow is not tied to the tree. This fact has to be inferred from the very statement of the test item. The third test item is based upon if-then statement i.e., the adolescent pupils should be in a position to accept absurd answers. The test items at serial numbers four and five defy simple arithmetic as taught in school if applied mechanically. The last item puts pupils on a wrong scent because they imagine two ducks swimming side by side in a single file. The first attracted answer of course is 6, upon which a constraint has to be applied. That is, the number of ducks should be as small as possible, that is, the smallest.

The data is as presented below :

Table 17

Means and standard deviations grade-wise as well as sex-wise for Questions Inviting Wrong Answers Problem

S. No.	Problem	Sex	G R A D E									
			VI		VII		VIII		IX		X	
			Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1.	Questions inviting wrong answers.	B	1.25	0.716	2.45	1.146	2.80	1.436	3.15	1.226	3.65	0.575
		G	0.80	0.768	2.45	1.605	2.15	1.182	2.05	1.849	4.95	1.093
		B+G	1.02	0.768	2.45	1.377	2.47	1.339	2.60	1.646	4.30	1.181

Interpretation

1. The capacity to grasp the essence of the problem is seen to increase with grade and with chronological age as the grade was controlled. However, if the criterion of 2/3 of the maximum (2/3 x 7) 4.66 is kept as the critical barrier, it is abundantly clear that all pupils with the exception of X grade girls appear to answer the various test items mechanically rather than formally as judged by the grade means. In other words, in this context, most of the pupils, practically speaking, are attracted more by the content rather than the form of the problem. This statement however can be toned down if we regard these questions as tricky ones. If this view is accepted, the very title of this problem, in our view ought to have pre-warned the pupils otherwise. That is, here are 6 test items which intentionally invite wrong answers.

2. While it comes to grasping the essence of the problem, heterogenity in performance on this problem comprising six items is firmly maintained.

3. As this aspect of the problem was not studied by the Genevans, it is safe to conclude that it is quite possible to evoke a wide range of concrete behaviour at the formal stage choosing suitable problems. Then, it amounts to saying that when adolescent pupils are not in a position to solve the problems successfully, they do not hesitate at all to bring into the problematic situation several extraneous considerations.

To be specific, when the supposedly available scheme of thought fails to solve the problem, the inferior one comes into play attracting in the process comments, criticisms and other arbitrary errors. Even when these become available for, they are attempts at searching the solution where any one such effort could work successfully, the business of formal thought is first to consider all such possibilities and eliminate the irrelevant variables through hypotheses stating and testing approach. If, this approach is absent, during problem solving, that is, the consequences of actions or thoughts are not deducted. That is, subjected to propositional logic, one can say safely that the adolescent pupils are in fact at the concrete stage of mental development. This point of view is shared by the following sample responses mentioned below :

Table 18

The Wrong Responses Emitted by the Pupils on the Questions Inviting Wrong Answers Problem

S. No. 1	Test Item 2	Responses 3
1.	A blind man with one eye can see up to a distance of 100 ft. How far can he see with two eyes?	200 ft.
2.	A cow is standing beside a tree. A rope or cord of 1 metre is tied around its neck. Tell how far from the tree she can go for eating grass?	1 metre 1 meter cord will be just enough to be tied around the cow's neck. So you cant tie it to the tree. It's a wrong question.

1.	2	3
3.	Suppose a donkey has two horns. How many horns in all have eight donkeys?	A donkey does not have horns. I can suppose one donkey has two horns(as in the question). In all,eight donkeys have 2 horns as the other seven does not have horns.
4.	A stick is 10 inches long. It is cut an inch per minute. How much time will it take for it to be cut into 1 inch pieces?	10 minutes. 1 minute.
5.	How many corners of the handkerchief are left if you cut off one of its corners with the help of a pair of scissors?	3 corners. 4 corners.
6.	Suppose some ducks are swimming under a bridge in a single line. Two ducks in front, two in the middle and two behind. How many ducks are there in all? The number of ducks should be as small as possible, that is, the smallest.	2 ducks 6 ducks 3 ducks, as they are going in a single line. Question is wrong because it says ducks are going in a single line and then two in front, two in the middle and two behind.

Conclusion

The thinking processes of adolescent pupils were investigated, using twelve Piaget type tasks, which arose from five categories: Stating of hypotheses, Testing of hypotheses, Permutations and combinations, Problem sensitivity and Grasping the essence of the problem, through the questionnaire method. The qualitative analysis of these problems revealed the following:

1. The four problems of stating of hypotheses have attracted a wide spectrum of thought.

2. When it comes to stating hypotheses to a particular problem on consideration in every possible form, adolescent pupils appear to be generous in stating them as judged by the total frequency of the hypotheses emitted. However, most of the adolescent pupils miss most of the hypotheses as judged by means alone regardless of the individual hypotheses. This suggests that the hypotheses are set up the way the problem is seen by the individual adolescent pupil.

3. Whereas the mean performance on this variable (Stating hypotheses) increases with grade and indirectly with chronological age, the variability of the various groups tends to become more or less homogenous at the closing grade of the study which, however, is reversed when it comes to testing hypotheses. Despite this oddity, the mean performance on testing hypotheses shows an increasing trend with grade.

4. Sex differences with occasional fluctuations exist favouring girls, across grades as well as across problems of testing of hypotheses, contrary to the findings of Vaidya and Sandhu. Whereas for the problems of permutations and combinations, no significant sex difference is seen.

In case of problems of permutations and combinations, the mean performance with minor fluctuations here and there and except a major fluctuation in grade IX for magic seed problem, increases with grade. However, all the adolescent pupils of this study were not in a position to exhaust all the possible combinations.

Ability to formulate difficult questions with minor fluctuations is found to increase with grade.

The grade means on problem sensitivity revealed that boys asked more questions than girls in all grades except VII and IX.

Despite divergence in aims and objectives, modes of presentation and nature of sample of the various studies in the Piagetian context, it is not only seen that the major part of adolescent thought is characterized by erratic behaviour (pre-logical thought and concrete behaviour) but also a sort of parallelism in sample responses exists when the quantitative thought developed logically tends to attain identify in thought Except the maintenance of sequence of development, the Piagetian age ranges have no relevance as such is clearly shown in this study. It is precisely for this reason that a given problem or a part of the problem is solved successfully not only within individual grades but also across the grades as well.

Majority of the adolescent pupils are attracted more by the content rather than the form of the problem.

CHAPTER V

[illegible]

WITH

[illegible]

CHAPTER V

FACTORIAL STRUCTURE OF ADOLESCENT THOUGHT
WITH
SPECIAL REFERENCE TO THE EXCLUSION OF VERBAL [illegible]
DURING ADOLESCENCE

Background

"Factor analysis is a statistical technique for reducing or simplifying a large number of variates in experimental data to a smaller number of hypothetical variates that represent weighted sums of the observed variates" (The New Encyclopaedia Britannica, 1979). When a large number of variables causally intertwined in a complex way is subjected to factor analysis, a minimum number of factors appear which if properly hypothesized are easily interpretable. However, the interpretations of the results of factor analysis, as is true of all scientific interpretations, are tentative. Factors are not eternal verities. They only represent the fundamental underlying sources of variation operating in a given set of scores, got under specific conditions. These factors are generally difficult to interpret from psychological angle as they are 'blurred averages' which reflects only the 'end products' of the human mind. Secondly, when the individual factor loadings on the significant factors are properly rotated, it yields the mathematical information about the behavioural composition of the included tests and variables and thus a source of direct

and concrete evidence of test validity. It was attempted to sample 'Exclusion of Variables' - Scheme of Thought, through a series of problems along with other variables, to test whether it appears factorially.

Early slow and crude methods in factor analysis have been supplanted by more elegant, computer-generated solutions. A wide variety of equally accurate methods and procedures are available for factorizing effectively a given correlation matrix. Regarding the operational aspect of factor analysis, two schools of thought exist. The first one is the British school of thought whose advocates are Brown, Burt, Cattell, Alkoussy, Eysenck, Herman, Holizinger, Spearman, Stephenson, Thomson and Vernon. They believe in the Hierarchical Group Factor Theory. And, the second is, the American school of thought where works of Thurstone, Kelley, Paterson, and Elliot, Alexander and Guilford are prominent. They advocate the Multiple Factor Theory. According to the British school, "all branches of intellectual activity have in common a fundamental function (or group of functions) where as the remaining or specific elements of the activity are seen in every case to be wholly different from that of all others". The American school postulates that the cognitive functions are based on "a number of components of more nearly equal variances" the multiple factors. Though both the schools have their own specifications regarding the interpretations of the common variances operating among the different tests of cognitive abilities, they convey almost the same sort of information. Holzinger and Herman(1938)

and Eysenck (1939) demonstrated quite early that the contents of group factors correspond very closely to that of multiple factors. As this study drew inspiration from the British school of thought, the technique chosen for factor analysis was the Principal Axes Method.

Some Factor Analytic Studies

Taking a historical view from our stand point only. Thurstone (1938) identified three types of reasoning ability: inductive reasoning, deductive reasoning and restricted reasoning through factor analysis. Guilford et al (1956) using fact and imagination, gave the three dimensional model of the intellect with hundred and twenty factors of intelligence. Lunzer and Humphrey (1966); and Lovell and Butterworth (1966) found a "Central intellective ability" or formal operational thought a pre-requisite for solutions of problems involving proportionality. Dudek, et al (1969) found an intertask consistency of Piaget's levels representing a general Piagetian factor independent of any general intelligence factor entering into the Binet scale. Stephens, et al (1969) in their study on 6 to 10 year olds found significant correlations of WISC verbal I.Q., performance I.Q. and a full scale I.Q. with Piagetian task of reasoning and formal thought. A general intelligence factor alongwith three factors on Piagetian measures appeared.

Hart (1971) got a bi-factor structure when scores on eight measures were factorised. Of the eight measures four were of formal operations : Pendulum task, Conservation of

motion on a horizontal plane, equilibrium in the balance and projection of shadows. One test was on verbal intelligence and the other three on formal reasoning in biology, history and literature. These were administered on 90 students of above average scholastic ability belonging to age groups of 13, 16 and 19 years. He found a large substantial first factor of formal operations and a second factor related to content which distinguished tasks from tests. Verbal and non-verbal intelligence components were found in formal thought.

Hooks (1973) attempted to measure the development of formal operations of students studying in grades 7th, 8th and 9th consisting of 190, 195 and 175 pupils respectively. He administered (1) Piaget's test of conservation of volume, (2) Peel's story test to measure logical reasoning and (3) Reimers's test of the understanding of correlation and the ability to use combinatorial analysis on them. Factor analysis yielded factors which could be classified as formal operations or verbal reasoning or numerical ability. As operationally defined by the tests, the exclusivity of formal operations and verbal reasoning was indicated by the loadings of the items. Abramowitz (1975) conducted a study on a group of 32 seventh grade students of 12-13 years. A revised version of Karplus's proportionality test organised into test booklets containing six tasks was administered to the subjects in group settings. All the tests that had to do with the handling of fractions were loaded on factor I which accounted for 53.7% of the

variance; the average proportionality score and ability were loaded on factor II which accounted for 26.6% of the variance; the size contrast, the ratio contrast and correlative test of inverse relations were loaded on factor III which accounted for 19.7% of the variance. This depicted the nature of the components of proportional thought as the skill tests of facility with fractions load on a different factor than those involving proportionality. Guerin (1975) investigated formal thought with the help of Raven's test of logical operations using Guttman's simplex analysis, as well as Keiler's alpha factors models' and independent cluster transformations and concluded the logical multiplication, compensation, proportional thinking, ordinality, and correlational thinking did not at all show hierarchical character. According to him, the formal thought or logical operations have two factors, namely, 'grouping concrete operational and coordinating concrete logical'. The logical operation of compensation was found to relate to both factors and represented a 'transition operation between the purely concrete operations and the purely logical or formal operations'. Mathway (1975) found that Piagetian measures bore a modest positive degree of relationship to performance on traditional measures of intelligence, and thus, clarified that the two types of measures were neither totally distinct nor totally identical. Both the measures were found to be contributing to a general intelligence factor. He also found that Piagetian factors were having a dominant concurrent achievement, thus, pointed out the way to new and possibly more reliable and valid predictors of achievement.

Vaidya (1964) investigated problem solving ability of adolescents using questionnaire approach (N = 60) as well as individual approach (N = 31), with the help of Piaget type tasks and other variables: intelligence, age, 11+ test scores on Arithmetic and English, persistence, maladjustment and interest in things. The data when factorially analysed by Hotelling method, revealed ten factors of which only the following four: Attainment factor, Practical factor, Interest factor and Adjustment factor, were found significant and were interpreted after rotation. Vaidya (1975) years later, conducted a more elaborate study, on a sample of 200 adolescent pupils studying in grades VI to X with equal number of boys and girls in each grade, to investigate their thought processes with problems inhering a continuous chain of reasoning. As many as 45 variables were used in this study. When the data were subjected to factor analysis by the Hotelling method, ten factors appeared which were rotated by Varimax and then interpreted. The ten factors extracted in this study are : Schematic Learning, General, Adjustment, Problem Orientation, Sensing Problems, Symbolization, Testing hypotheses, using constant difference, aspect character, seeing the problem as a whole, intelligence.

Joshi (1970) tried to study the acquisition of algebraic concepts during the secondary school years and found by using the Cluster Analysis Technique, only one common factor appeared. The Centroid Method, indicated the existence of two factors,

viz. 'Algebraic Aptitude' and 'Symbolic Substitution'. Misra and Vaidya (1975) studied the thought processes of 50 science students of grade [illegible] using five Piaget type problems in the questionnaire form. The experiments involved in the problems were demonstrated in small groups of 10 pupils each. The mathematical structure of these problems after the rotation revealed five factors: General Adjustment Factor, Ability to see the Problem as a whole, Formulating Hypotheses, Interest in Generating Difficult Problems and Newness of the Problem.

Tenshu (1980) investigated the structure of formal thought using Piaget type tasks (loaded with scientific contents) on 986 adolescent pupils (505 boys and 481 girls) belonging to age groups of 11+, 12+, 13+, 14+ and 15+ studying in grades VI to X respectively. Besides the ten Piaget type tasks the other variables considered were Intelligence, Reasoning ability, Space Relations, Adjustment, Personality traits and Academic achievement. The data were factor analysed by the Principal component method and then rotated by Varimax. The resultant factors were: General intellectual factor, Academic achievement factor, Adjustment factor, Behavioural factor, Emotional factor, Temporal factor, Group factor of adolescent thought-I, Social factor, Group factor of personality-I, Abstract thinking factor, Group factor of adolescent thought-II, Stating and testing of hypotheses, Group factor of personality -II, Group factor of adolescent thought-II. Jain (1981) obtained three factors: Schematic learning general, Creativity, and Achievement when he tried to study the Problem solving

behaviour in physics of certain groups of adolescent pupils of class XI (N = 100).

The Present Study

What do the above mentioned factorial studies regardless of samples and techniques of analysis show? They show that a comprehensively intensive study in the Piagetian context is urgently needed.

To reiterate, the objective of subjecting the present data to factor analysis was to explore to existence of one of the Piagetian Scheme of Thought, hypothetically named as 'Exclusion of Variables', developing during adolescence as postulated by the Geneva school with several outside variables included. Precisely speaking, the following variables were included in the study.

Table 19

List of Thirty Nine Variables With Their Codes

Serial No. of the variable	Description	Short notation used
1.	Age	Ag.
2.	Intelligence	I.Q.
3.	Reserved/Outgoing	A
4.	Concrete thinking / Abstract thinking	B
5.	Emotionally less stable / Emotionally stable	C
6.	Phlegmatic/Excitable	D

Serial No. of the Variable	Description	Short notation used
7.	Obedient/Assertive	E
8.	Serious/Heedless	F
9.	Expedient/Conscientious	G
10.	Shy/Adventurous	H
11.	Tough-minded/Tender-minded	I
12.	Zestful/Circumspect	J
13.	Secure/Insecure	O
14.	Group dependent/Self sufficient	Q_2
15.	Uncontrolled/Self-disciplined	Q_3
16.	Relaxed/Tense	Q_4
17.	Abstract reasoning (DAT)	[illegible]
18.	Numerical ability (DAT)	NA
19.	Mechanical reasoning (DAT)	[illegible]
20.	Space relations (DAT)	[illegible]
21.	Verbal reasoning (DAT)	VR
22.	Spelling (DAT)	Sp
23.	Sentences (DAT)	Sen
24.	Language usage (DAT)	LU
25.	The flow of liquid through a tube problem	S_1P_1(SCh)
26.	The simple pendulum problem	S_1P_2(SCh)
27.	The ramp problem	S_1P_3(SCh)
28.	The seed problem	S_1P_4(SCh)

Serial No. of the Variable	Description	Short notation used
29.	Stating of hypotheses	[illegible] (T)
30.	The flow of liquid through a tube problem	[illegible]
31.	The simple pendulum problem	[illegible]
32.	The rope problem	[illegible]
33.	The worms problem	[illegible]
34.	Testing of hypotheses	[illegible] (T)
35.	Digital problem	[illegible]
36.	The magic seeds problem	[illegible]
37.	Permutations and combinations	[illegible]
38.	Formulating questions problem	([illegible])
39.	Grasping the essence of the problem	([illegible])

The data of all the 39 variables included in the study for the entire sample (N = 200) were subjected to factor analysis to study the mathematical structure of adolescent thought. The steps undertaken in this regard are described ahead.

Correlation Matrix

A correlation matrix (39x39) was prepared and the serial order of the measures presented in the correlation matrix (Appendix 5) are described below :

1 -	Age
2 -	Intelligence
3 - 16	Personality Measures

17 - 24 Measures of LAP
25 - 39 Measures of Piaget Type Tasks

The Correlation Matrix was divided symmetrically by the diagnol and the total number of co-efficients of correlation when counted was found to be 741, of which 579 were positive and 162 negative. Out of the 579 positive correlations 275 were found significant at 0.01 level and 61 at 0.05 level and 243 insignificant. Out of the 162 negative co-efficients of correlation, as many as 154 were insignificant and of the 8 significant, 1 was found to be significant at 0.01 level and 7 at 0.05 level.

Obtaining the Factors

When the correlation matrix (39x39) described above was subjected to factor analysis, twelve significant factors having eigen values greater than one, were extracted and retained for Varimax Rotation. Results regarding the factor loadings of the original as well as the varimax rotated factors are presented in Appendices and respectively.

The eigen values, accumulated percentage of the total variance, and the percentage of common variance accounted for by the factors I to XII are as follows :

Contd.

Table 20

Eigen Values, Percent of Variance and Cumulative Percentage for the Twelve Factors

Factor	Eigen value	Percent of Variance	Cumulative Percentage
I	8.640[illegible]	22.2	22.2
II	2.80763	7.2	29.4
III	2.[illegible]47	6.7	36.1
IV	[illegible].10094	5.6	41.6
V	1.88731	4.8	46.4
VI	1.80370	4.6	51.1
VII	1.66557	4.3	55.4
VIII	1.25357	3.2	58.6
IX	1.16445	3.0	61.6
X	1.14637	2.9	64.5
XI	1.06[illegible]	2.7	67.2
XII	1.01326	2.6	69.8

Interpretation of Factors

To simplify the interpretation of factors and to draw attention only to those factor loadings which contributes for determining the nature of the factor, smaller factor loadings were ignored. However, there is no uniform criterion for judging how 'small' a factor loading should be, to be called 'small' to be ignored. Benjamin Fruchter (1967) has suggested that values of factor loadings less than .20 are, generally speaking, insignificant and hence can be ignored. Where as other researchers have ignored values upto .30 and some upto .35. In the present study, the factor loadings of the different variables on the various factors having values numerically less than .35 have been ignored while interpreting the factors.

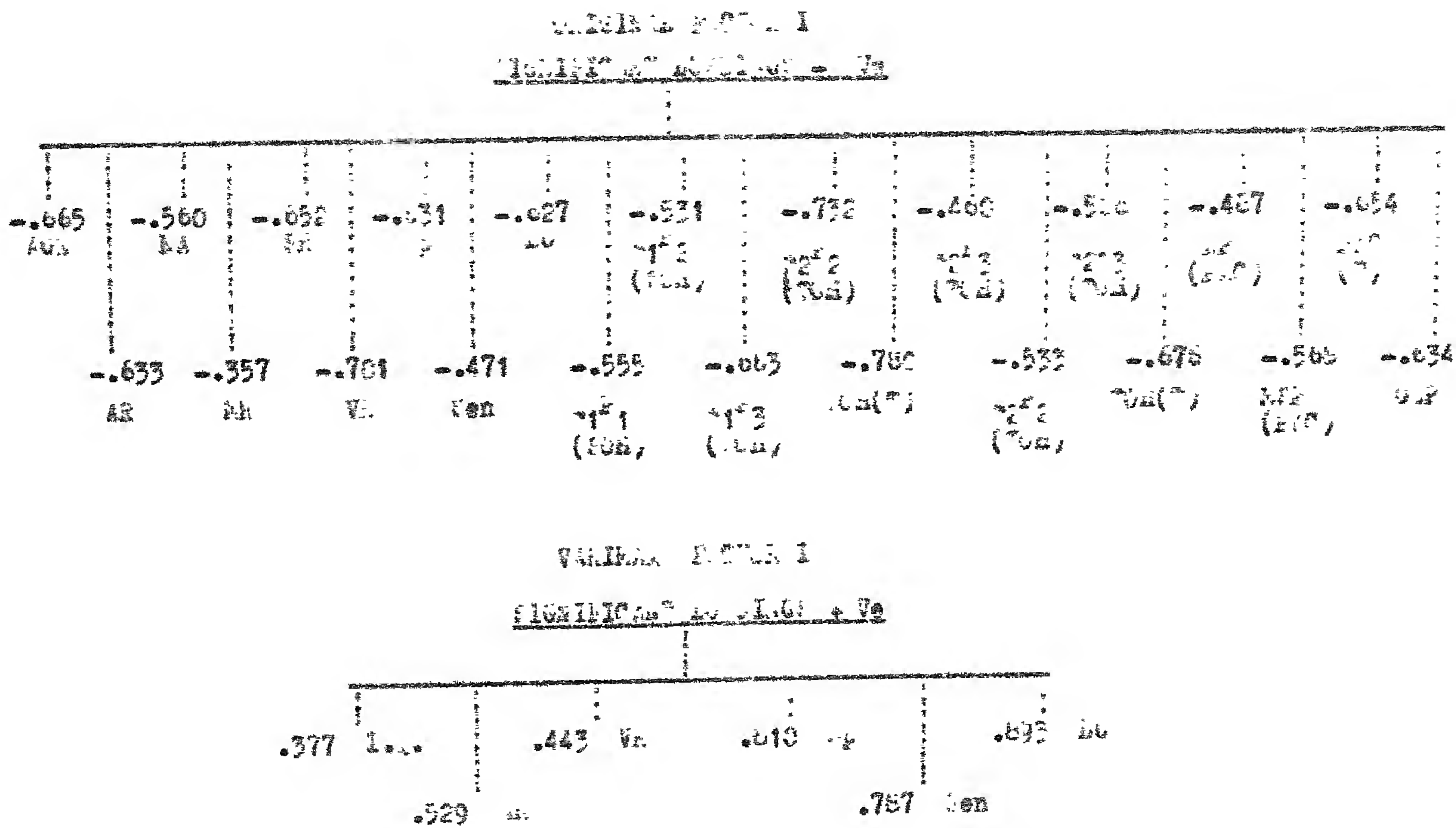


Fig. 42
Significant Loadings of Original and
Varimax Factor 1

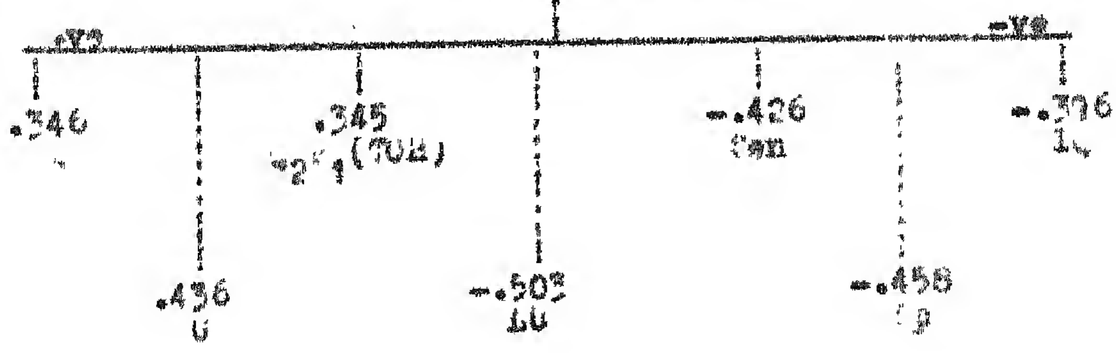
Factor I

Significant loadings of the different variables on factor I (Original as well as Varimax Rotated) have been shown in Fig. The 2[illegible] variables that have significant factor loadings on factor I are: [illegible], measure of aptitude ([illegible], [illegible], [illegible], [illegible], V[illegible], [illegible]p, [illegible]en, [illegible]), finger type tests [illegible](T_1)(TUn), [illegible](T_2)([illegible]), [illegible](T_3)([illegible]), [illegible](T_4)([illegible]), [illegible](T_1)(TU[illegible]), [illegible](T_2)(TU[illegible]), [illegible](T_3)(TUR), [illegible] ([illegible]), [illegible] ([illegible]) and schemes of thought ([illegible](T), TU[illegible](T), [illegible](T), [illegible]). Thus, this factor has brought together variables of age, aptitude and schemes of adolescent thought.

Varimax rotated factor I shows a clearer picture with significant loadings on six variables: Intelligence (I.[illegible]), measures aptitude ([illegible], Va, Sp, Con and LU). The loadings are found to be varying between -.5[illegible] to .893. The highest loading is for the variable language usage (.893). So, factor I is named as Language factor.

ORIGINAL FACTOR II

SIGNIFICANT LOADINGS



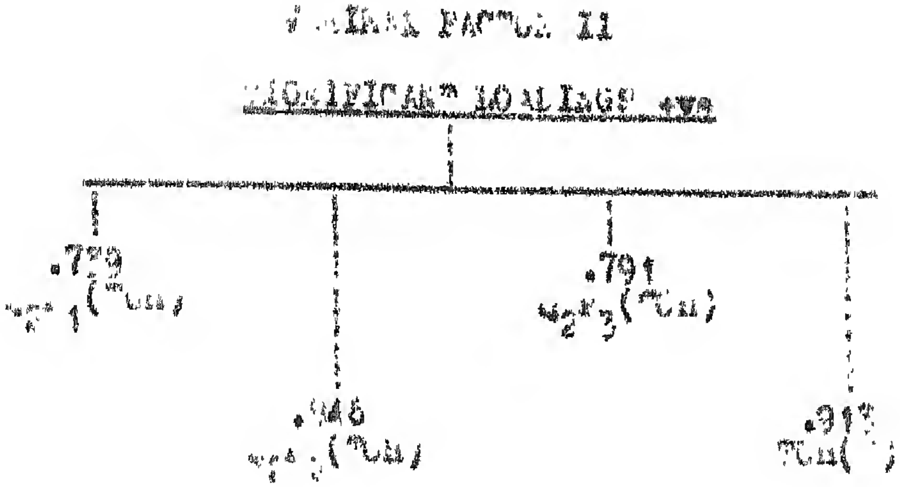


Fig. 43

Significant Loadings of Original and Varimax Factor II

Factor II

Original significant factor loadings on this factor shows a bipolar structure. Three variables, two of personality (A and Q), and one Kinget type test ($v_2 r_1$ TCm) have positive signs and four variables I., Sp, Sen and AU have negative signs.

The Varimax Rotated Factor II shows only four significant loadings which are all positive on variables all of which belong to testing of hypotheses. The factor loadings range between .739 and .913. The highest loading is on the variable testing of hypotheses (Total). So the II Factor is named as Exclusion of Variables (Testing of Hypotheses).

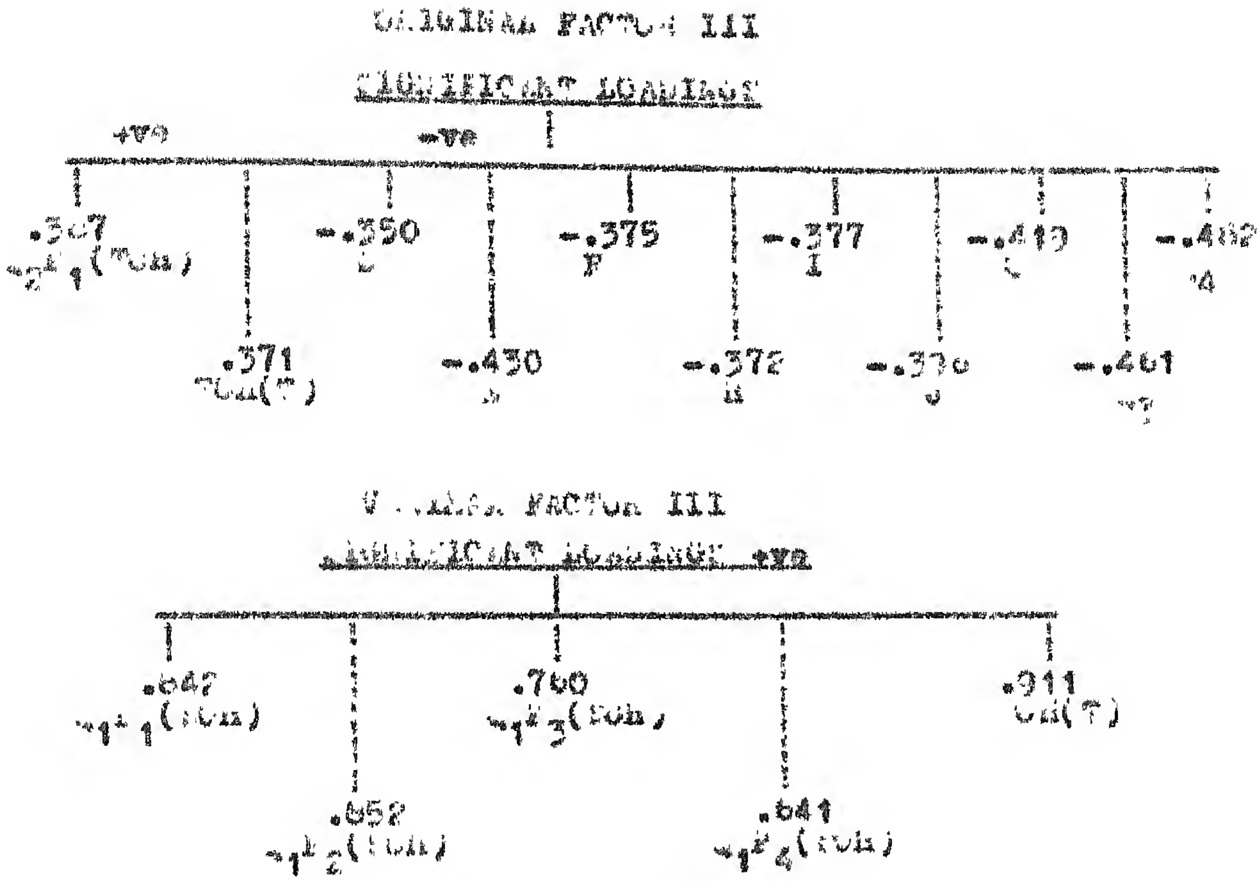


Fig. 44
Significant Loadings of Original and Varimax Factor III

Factor III

Of the 11 significant loadings on this factor (Fig.44) two : w_2F_1(TOH) and TOH (T) and nine personality variables (A, E, F, H, I, J, O, w_3 and w_4) are found to have negative signs, making it bipolar.

In the case of Varimax Rotated Factor III only the variables of stating of hypotheses w_1F_1(SOH), w_1F_2(SOH), w_1F_3(SOH), w_1F_4(SOH), and SOH(T) shows significant loadings. The loadings on this factor varies between .641 and .911. The

highest loading is on stating of hypotheses (Total). So, Factor III is named as Exclusion of Variables (stating of hypotheses).

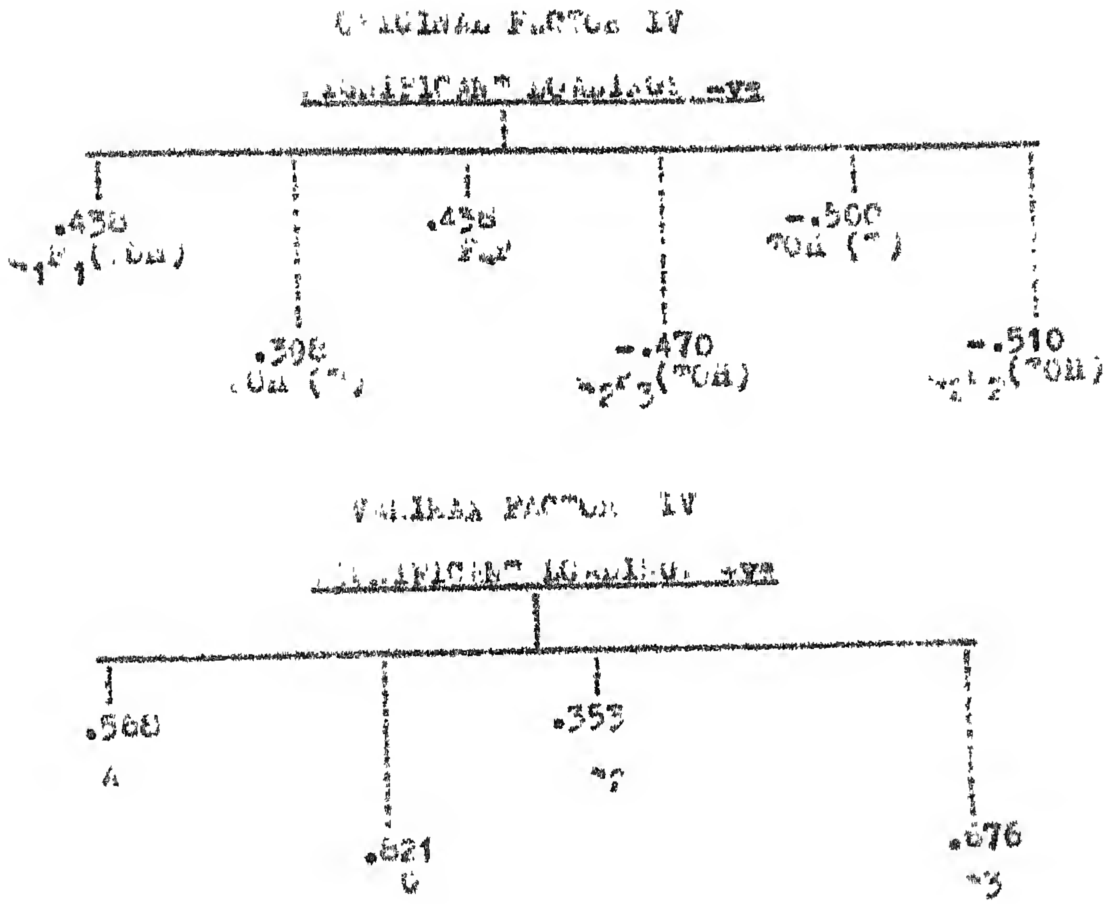


Fig. 45
Significant Loadings of Original and Varimax Factor IV

Factor IV

Fig. 45 shows six (Original) significant factor loadings of which three w_1k_1(TOH), SOH(T) and R_w have positive signs and w_2k_3(TOH), TOH(T) and w_2k_2(TOH) have negative signs showing a bipolar structure.

However, the Varimax Rotated Factor IV have only four nificant loadings on personality variables: A, G, Q_2 and Q_3, ich are all positive. As the highest loading on this factor for the personality dimensions: Expedient/conscientious (G), e factor is named as Super Ego Strength.

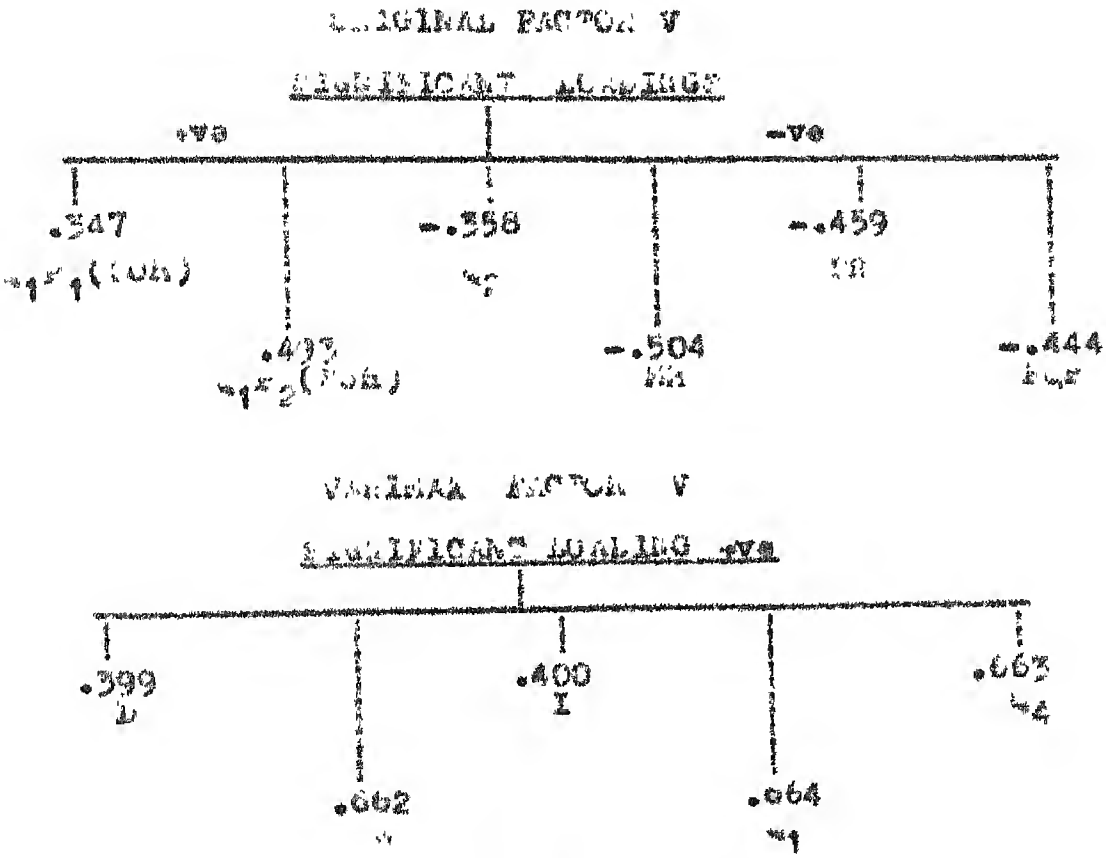
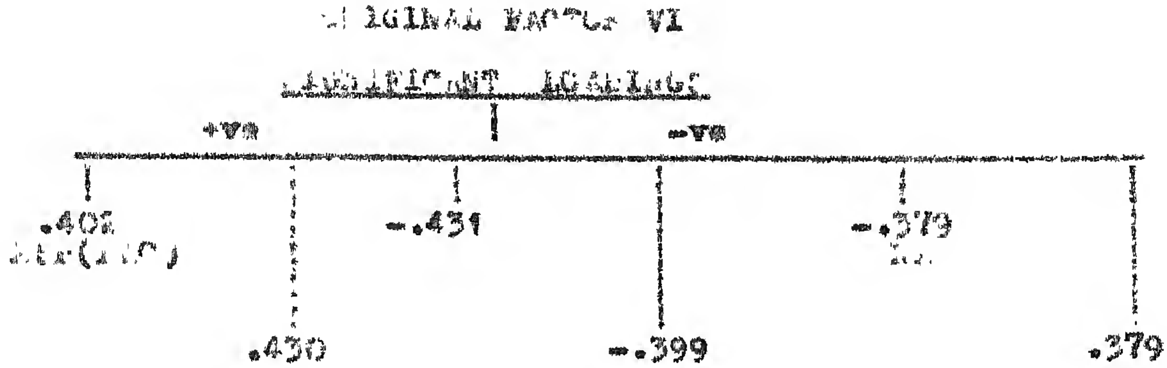


Fig.46
Significant Loadings of Original and Varimax Factor V

actor V

Original Factor V shows six significant loadings of ich two A_1F_1(SOH), A_1F_2(FOH) possess positive signs and the est four: A_2, AM, EB and F.F possess negative signs making it bipolar factor.

The Varimax Rotated Factor V (Fig.46) shows five significant factor loadings ranging between .399 and .664 which are all positive. Three personality factor [illegible] (.662), [illegible](.667) and [illegible] (.664) are found to have almost the same loading. So, the Factor V is named as Group Factor of Personality (Dominance, Guilt Proneness, Ego Strength).



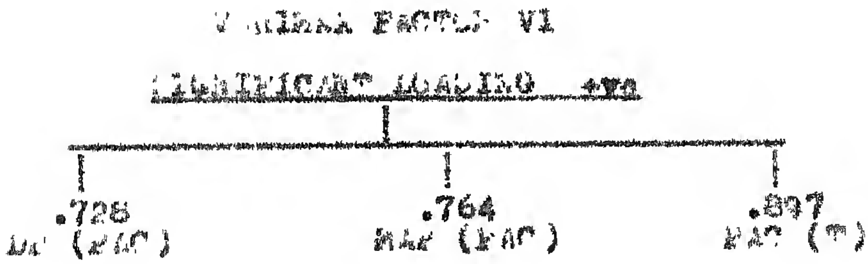


Fig. 47
Significant Loadings and Original and Varimax Factor VI

Factor VI

This factor has significant loadings on six variables (MSP(PAC), PAC(T), [illegible], [illegible], Q_4 and AA) of which first two are positive and the other four negative.

Varimax Rotated Factor VI shows significant loadings on only three variables LP(PAC), MSP(PAC) and PAC(T) ranging

between .726 and .597. The highest loading is of Permutation and Combination (Total). So, the Factor VI is named as Permutations and combinations.

ORIGINAL FACTOR VII

SIGNIFICANT LOADINGS +ve

.357	.457	.496
LP(PAC)	LSP(PAC)	PAC(T)

VARIMAX FACTOR VII

SIGNIFICANT LOADING +ve

.597	.823	.546
I.Q.	MR	SR

Fig. 48
Significant Loadings of Original and Varimax Factor VII

Factor VII

Only three variables, LP(PAC), LSP(PAC) and PAC(T) are found to have significant loadings which are all positive.

However, the Varimax Rotated VII shows highly significant loadings on three other variables I.Q. MR and SR ranging between .546 and .823. As the highest loading is for Mechanical Reasoning, the Factor VII is named Mechanical Reasoning.

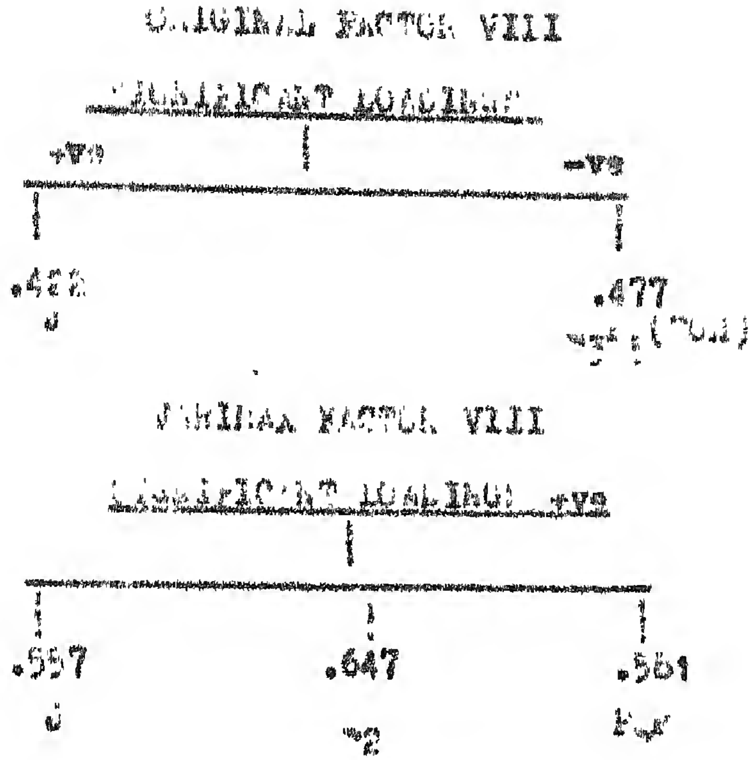


Fig. 49
Significant Loadings of Original
and Varimax Factor VIII

Factor VIII

The Original Factor VIII shows significant loadings for only two variables J and Q_2F_5(Tom). Whereas the Varimax Rotated Factor VIII shows significant loadings on three variables, two of personality (J and Q_2) and Formulating question problem. The highest loading is on the personality dimensions 'Group dependent/self sufficient (Q_2)'. So the Factor VIII is named as Self Sufficiency.

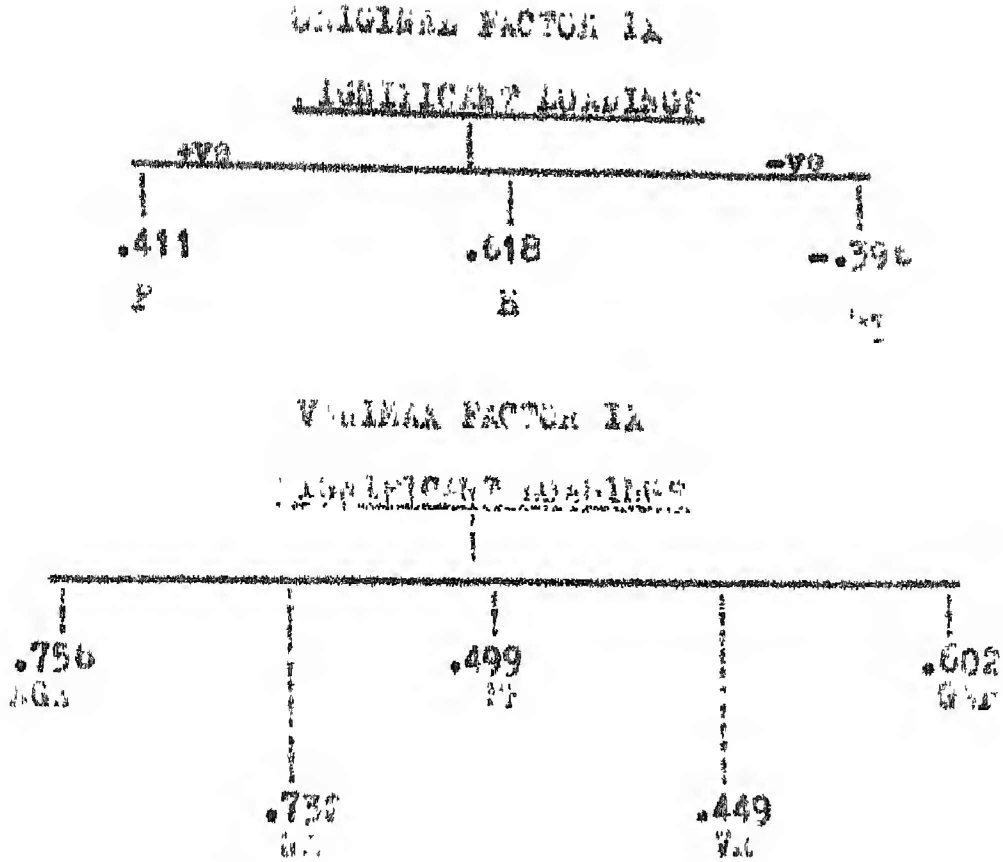


Fig. 50
Significant Loadings of Original and Varimax Factor IA

tor IA

Three personality variables P, H and ... have significant dings on this original factor their loadings ranging between 6 and .618. The Varimax Rotated Factor IA (Fig.50) shows t Age, MA, Sh, Va and G.P have significant loadings on this tor, ranging between .449 and .756. The highest loading on e factor is for Age. Factor IA is named as Age Factor.

ORIGINAL FACTOR A

SIGNIFICANT LOADINGS

+ve -ve

.427 -.403 -.3[illegible]

I.Q. AGE M(PAC)

VARIMAX FACTOR A

SIGNIFICANT LOADINGS +ve

.680 .788

F H

Fig.51
Significant Loadings of Original and
Varimax Factor A

Factor A

I.Q., Age and M(PAC) are found to have significant loadings on the original factor A. I.Q. has a positive loading and the other two negative showing a bi-polar structure. But the Varimax Rotated Factor A shows significant loadings on personality variables F(.680) and H(.788). The highest loading is on the personality dimension Shy-Adventurous (H). So Factor A is named as Parmia.

ORIGINAL FACTOR AI

SIGNIFICANT LOADINGS

+ve   -ve

.369   -.365
O   C

VARIMAX FACTOR AI

SIGNIFICANT LOADINGS

+ve   -ve

.619   .434   -.566
C   I   D

Fig. 52
Significant Loadings of Original and Varimax Factor AI

Factor AI

Original Factor AI shows a bipolar structure with the personality variable O with a significant posivie loading and personality variable 'C' with a significant negative loading. When Varimax Rotated Factor AI is looked into, three personality variables are found to have significant loadings on this factor. Two positive and one negative making it bipolar. The highest loading is on the personality dimension Emotionally less stable/Emotionally stable (C). This factor is named as Ego Strength.

ORIGINAL FACTOR XII

SIGNIFICANT LOADINGS +ve

.492
B

VARIMAX FACTOR XII

SIGNIFICANT LOADINGS

+ve -ve

.711
B

-.627
Q_3F_5(TOA)

Fig. 53
Significant Loadings of Original
and Varimax Factor XII

Factor XII

The Original Factor XII shows significant loading only, on one personality variable 'concrete thinking / Abstract thinking (B)'. The Varimax Rotated Factor XII shows significant loadings on two personality variables 'B' and Q_3F_5(TOA). The highest loading (.711) was for the personality dimension 'concrete thinking-Abstract thinking' (B). So, the Factor XII is named as Intelligence.

Fig. 54
Graphic Relationship between the Twelve Factors and their Eigen Values

However, when these twelve factors are subjected to 'Scree test' as propounded by Cattell, four factors from bottom upwards can be eliminated, resulting in the following eight factors :

Factor I	Language Factor
Factor II	Exclusion of Variables (Testing of Hypotheses)
Factor III	Exclusion of Variables (Stating of Hypotheses)
Factor IV	Super Ego Strength
Factor V	Group Factor of Personality (Dominance Guilt proneness, Ergic tension).
Factor VI	Permutations and Combinations
Factor VII	Mechanical Reasoning
Factor VIII	Self Sufficiency

Concluding Statement

Where does this whole discussion lead to? It conveys that small sampled studies using limited tests have not yielded the same factors. Secondly, there has been little uniformity in the choice of tasks for facilitating comparison of findings. Thirdly, out of all the studies made so far, the ones by Vaidya and Sandhu are the most detailed. Still, they have missed the stages of mental development developed earlier to the formal stage. Fourthly, there is no full fledged study which uses all the Piaget type tasks along with several outside variables.

Keeping in mind these restraints, the present study investigated one of the schemes of thought (Exclusion of Variables) in relation to several outside variables. If all

the findings are consolidated, the following incomplete picture for the various reasons stated above appears to emerge.

Table 21

The Current Picture of the Factorial Structure of Adolescent Thought

S. No.	Factor		Psychological Interpretations	Author(s)
1.	First Factor	(i)	General Intellectual Factor	Abou Hatab (1964), Beard (1957), Lawsnos (1969), MacArthur (1968), Peel (1955), Sandhu (1980), Stavor & Patel (1979), Tuddenham (1970), Vernon (1971), Vaidya and Sandhu (1981)
		(ii)	Schematic Learning General	Bart (1971), Renner and Lawson (1975), Vaidya (1975), Jain (1982)
		(iii)	Attainment Factor	Vaidya (1964)
		(iv)	Algebraic Aptitude	Joshi (1970)
		(v)	General Adjustment	Vaidya and Misra (1975)
		(vi)	Formal Operational Thought	Abramowitz (1975)
		(vii)	Exclusion of Variables	Shayer (1978)
		(viii)	Language Factor	Padmini (1982)

1	2		3	4
2.	Second Factor	(i)	Practical Factor	Vaidya (1964)
		(ii)	Symbolic Substitution	Joshi (1970)
		(iii)	Adjustment	Vaidya (1975)
		(iv)	Seeing the Problem as a Whole	Vaidya and Misra (1975)
		(v)	Piagetian Cognitive Development	Stavor and Gabel (1979)
		(vi)	Academic Achievement Factor	Sandhu (1980), Vaidya and Sandhu (1981)
		(vii)	Creativity	Jain (1982)
		(viii)	Exclusion of Variables (Testing of Hypotheses)	Padmini(1982)
3.	Third Factor	(i)	Interest Factor	Vaidya (1964)
		(ii)	Problem Orientation	Vaidya (1975)
		(iii)	Formulating hypotheses	Vaidya and Misra (1975)
		(iv)	Piagetian Logical Operations Test	Stavor and Gabel (1979)
		(v)	Adjustment Factor	Sandhu (1980)
		(vi)	Stating and Testing of Hypotheses	Vaidya and Sandhu (1981)
		(vii)	Achievement	Jain (1982)
		(viii)	Exclusion of Variables (Stating of Hypotheses)	Padmini (1982)
4.	Fourth Factor	(i)	Adjustment Factor	Vaidya (1964)
		(ii)	Sensing Problems	Vaidya (1975)
		(iii)	Tackling Algebraic Symbols	Vaidya (1975)
		(iv)	Interest in Generating Difficult Problems	Vaidya & Misra(1975)
		(v)	Behavioural Factor	Sandhu (1980)
		(vi)	Super Ego Strength	Vaidya and Sandhu (1981) Padmini (1982)

1	2		3	4
5.	Fifth Factor	(i)	Problem Orientation	Vaidya (1975)
		(ii)	Symbolisation	Vaidya (1975)
		(iii)	Newness of the Problem	Vaidya and Misra (1975)
		(iv)	Emotional Factor	Sandhu (1980)
		(v)	Premsia	Vaidya and Sandhu (1981)
		(vi)	Group Factor of Personality(Dominance, Guilt Proneness, Ergic tension)	Padmini (1982)
6.	Sixth Factor	(i)	Testing Hypotheses	Vaidya (1975)
		(ii)	Using Constant Difference	Vaidya (1975)
		(iii)	Temperamental Factor	Sandhu (1980)
		(iv)	Self Sufficiency	Vaidya and Sandhu (1981)
		(v)	Permutations and Combinations	Padmini (1982)
7.	Seventh Factor	(i)	Aspect Character	Vaidya (1975)
		(ii)	Using Constant Difference	Vaidya (1975)
		(iii)	Group Factor of Adolescent Thought-1	Sandhu (1980)
		(iv)	Permsia	Vaidya and Sandhu (1981)
		(v)	Mechanical Reasoning	Padmini (1982)
8.	Eighth Factor	(i)	Exclusion of Variables	Vaidya (1975)
		(ii)	Aspect Character	Vaidya (1975)
		(iii)	Social Factor	Sandhu (1980)
		(iv)	Adjustment	Vaidya and Sandhu (1981)
		(v)	Self-sufficiency	Padmini (1982)

9. Ninth Factor	(i)	Combinatorial Grouping	Vaidya (1975)
	(ii)	Seeing Problem as a whole	Vaidya (1975)
	(iii)	Group Factor of Personality-I	Sandhu (1980)
	(iv)	Space Relations	Vaidya and Sandhu (1981)
	(v)	Age	Padmini (1982)
10. Tenth Factor	(i)	Intelligence	Vaidya (1975)
	(ii)	Verbal Description Procedures	Vaidya (1975)
	(iii)	Abstract Thinking Factor	Sandhu (1980)
	(iv)	Surgency	Vaidya and Sandhu (1981)
	(v)	Parmia	Padmini (1982)
11. Eleventh Factor	(i)	Group Factor of Adolescent Thought-II	Sandhu (1980)
	(ii)	Excitability	Vaidya and Sandhu (1980)
	(iii)	Ego Strength	Padmini (1982)
12. Twelfth Factor	(i)	Stating and Testing of Hypotheses	Sandhu (1980)
	(ii)	Intelligence	Padmini (1982)
13. Thirteenth Factor		Group Factor of Personality-II	Sandhu (1980)
14. Fourteenth Factor		Group Factor of Adolescent Thought-III	Sandhu (1980)

* Some factors from the bottom upwards could be eliminated through scree test.

This summarization attempts to show, as already mentioned, that we have to go a long way in uniting the two opposing lines of inquiry regarding the investigation of the developing nature of intelligence on which empirically abundant data are not available. So, perhaps we now know how and where to strike for unfolding the phenomenon which was not the case scantly over a decade ago.

CHAPTER VI

[illegible]

CHAPTER VI
OTHER STATISTICAL RELATIONSHIPS

Introduction

It is usually difficult to subject data on problems conceived within the Piagetian context to statistical analysis. There are many reasons for the same. First, the formal stage of mental development as visualized by the Genevans is yet to be scratched. Secondly, it does not matter which individual is selected because the concept of the individual for testing purposes whether exploratory or otherwise is raised to the status of an 'Universal Child'. Thirdly, if approach other than the 'Methode Clinique' is used, one is not ensured fully of the maximal performance of the individuals participating in the study. Fourthly, the similar observation applies to the development of test instruments so far as their reliability and validity co-efficients, usually low, are concerned. Despite these limitations which are in a way shared more than equally by the personality tests, projective tests in particular, the Piagetian tasks more or less in the same view too have uncovered a lot of pupil thought which is relevant to the development of quantitative fields from the psychological angle. It is this aspect of the problem which really demands scientific attention, for, it is largely ignored in psychometric studies. Hence, the lesson from Piagetian research is that intellectual phenomena should be studied developmentally before it is psychometrically

measures. In this study, the ability to set up hypotheses and test them appears to develop with the onset of adolescence. Within the above mentioned limitations, the present chapter attempts to answer the following questions which have not been attempted in the fourth chapter.

1. How many hypotheses can an adolescent pupil state of the various ages?
2. What is the incidence of formal reasoning among the present group of adolescent pupils taken in this study?
3. What are the sex-differences on Piaget-type tasks and other variables included in this study?
4. How are the abilities to set up and test hypotheses related to the various variables included in this study?
5. What are the characteristic differences between the successful and unsuccessful problem solvers?

The answers to the above questions enable to test the following hypotheses proposed to be tested in this study.

Hypotheses

1. Adolescent pupils are in a position to set up hypotheses in all the age groups.
2. The given hypothesis is tested successfully in all the age groups.
3. Boys and girls do not differ significantly in performance on Piaget type tasks, aptitude tests and personality variables.
4. There exists a significant relationship between the measures of Exclusion of variables (Stating and Testing of hypotheses) with the measures of : Age, I.Q., Aptitude (DAT), Personality (HSPQ), Permutations and

combinations, problem sensitivity and grasping the essence of the problem.

5. There exists significant differences between successful and unsuccessful problem solvers on : Stating of hypotheses, Testing of hypotheses and personality traits ([illegible]).

Answers Obtained

Q.1 How many hypotheses can an adolescent pupil state at the various ages?

Table No. 22

Gradewise Mean for the Four Problems of Testing of Hypotheses

S.No.	Problem	Grade				
		VI	VII	VIII	IX	X
1.	The flow of liquid through a tube problem	5.92	7.70	8.50	7.00	10.05
2.	The simple pendulum problem	5.00	6.55	7.35	8.27	8.97
3.	The ramp problem	3.70	9.12	6.42	7.32	9.77
4.	The seed problem	7.00	12.32	12.92	9.90	20.00

The adolescent pupils are in a position to set up hypotheses in all grades. However, the number of hypotheses emitted shows an increasing trend with grade. As judged by the frequency, the ability to state hypotheses increases by two to three times not only across the grades but also across the problems as well. When seen in a larger perspective, this finding supports similar findings elsewhere except that, the age range of the sample stands downgraded to 10+. In short, pupils at 10+, emit about four to seven hypotheses per problem

depending upon the nature of the problem as well as its mode of administration, here it being the questionnaire approach with negligible difficulty in language.

Q.2 What is the incidence of formal reasoning among the present group of adolescent pupils taken for the study?

Table No. 25

Percentage of Pupils at Three Levels of Thinking Grade-wise and Combined on the Three Problems of Testing of Hypotheses

S. No.	Grade	Level of thinking	The flow of liquid through a tube problem	The simple pendulum problem	The ramp problem
1.	VI	Below formal	15.0	52.5	67.5
		Partially formal	77.5	40.0	30.0
		Fully formal	7.5	7.5	2.5
2.	VII	Below formal	12.5	27.5	32.5
		Partially formal	80.0	27.5	50.0
		Fully formal	7.5	45.0	17.5
3.	VIII	Below formal	20.0	40.0	32.5
		Partially formal	47.5	30.0	50.0
		Fully formal	32.5	30.0	17.5
4.	IX	Below formal	0.0	2.5	15.0
		Partially formal	65.0	52.5	52.5
		Fully formal	35.0	45.0	32.5
5.	X	Below formal	2.5	5.0	17.5
		Partially formal	80.0	57.5	47.5
		Fully formal	17.5	37.5	35.0
6.	Combined (VI to X)	Below formal	10.0	25.5	31.0
		Partially formal	69.0	37.0	46.5
		Fully formal	21.0	37.5	22.5

The three problems, namely, The flow of liquid through a tube problem, The simple pendulum problem, and The ramp problem, each having two hypotheses were used for investigating the hypotheses testing ability where each problem was considered as a whole. The data in this respect are presented above (Table No.23) where the individual frequencies show the number of pupils mastering a given problem at three levels, namely, below formal, partially formal and fully formal. The percentage of pupils at these three levels both within the individual grades and across the three problems vary quite widely. The reason for this appears to be the nature of the problem as well as the past experience of individual pupil vary with the problem itself. It is precisely for this reason that about two-thirds of the VI grade pupils could not at all start attacking the ramp problem formally. The same pattern of observation is obtained when even as many as 17.5 per cent of the pupils of grade X could not attack the same problem formally. If, however, performances on this variable i.e., testing hypotheses are aggregated across the grades, it appears that as many as 31 per cent of the pupils are not in a position to tackle the problem formally at all. The corresponding percentage for those pupils, who are in a position to tackle the problem at the formal level fully, is as high as 37.5 per cent, which is again on a different problem, namely, the simple pendulum problem. If data are looked more closely, it can be hypothesized that the individual minds of our adolescent pupils have not yet become fully experimental which in other words means that adolescent thought as a whole

within the context of this study is a mixture of concrete thought (below formal) and developing formal thought (partially formal) which has yet to attain its equilibrium.

[illegible].3 What are the sex differences on Piaget type tasks and other variables included in this study?

The study of sex differences has been a matter of investigation in several studies including intelligence testing. Especially, large scale intelligence testing has shown that boys and girls score more or less equally as judged by their mean scores. Several studies from the highly developed countries have indicated sex-differences in attainment in science (Shaycoft et al, 1963). Tyler has shown that at the primary as well as at the higher primary stage, the sex difference in regard to ability and achievement is small in comparison with the 'variation within groups of the same sex'. Similarly Anastasi and others have shown that spatial, numerical and mathematical reasoning tests favour boys and verbal and linguistic studies favour girls. According to the All India Survey of Achievement in Mathematics (NCERT, 197[illegible]) under the leadership of Prof. [illegible].Mitra, "boys showed superiority over girls at all three levels... In the case of the co-educational schools, the sex differences get a bit diminished... Sex differences may, in fact, appear due to 'within group phenomena'." Another international publication by UNESCO entitled 'Science Education in Nineteen Different Countries' have indicated sex differences favouring boys in our country. Vaidya and Sandhu in their doctoral works have also indicated sex differences on

Piaget type tasks favouring boys. Some of the differences may be explained by the difficulty of the test items and perhaps lack of earlier experience with similar test items especially in the case of girls. The other reason could also be, perhaps the boys and girls were not equal in numbers in several study samples (Vaidya, 1979, excluded). To quote the report :

> The contribution to the sex difference is much more pronounced in the physical sciences than in the biological sciences. Whether the causes of this sex difference are innate, which seem unlikely or whether they are the result of traditional practices in child rearing and formal education, it is impossible to say at this juncture. It is clear that here is a problem that deserves further attention if justice is to be done to girls in the field of science.

Data on sex differences of this study are presented below on Piaget type tasks, intelligence, aptitude and personality traits.

Contd.

Table No.[illegible]

Mean, [illegible] [illegible] and t values for the Twelve [illegible] Test [illegible] Other Variables [illegible] in This Study

S.No.	Variables	Gr	N	Mean	S.D.	[illegible]	t	Sig.
1	2	3	4	5	6	7	8	9
1.	The flow of liquid through a tube problem (Stating of hypotheses)	[illegible]	100	6.47	2.642	0.264	-3.39	[illegible]
		[illegible]	100	7.75	3.106	0.313		
2.	The simple pendulum problem (Stating of hypotheses)	[illegible]	100	[illegible]	3.312	0.331	-3.64	[illegible]
		[illegible]	100	7.48	3.173	0.317		
3.	The ramp problem (Testing of hypotheses)	[illegible]	100	6.10	3.938	0.394	-4.60	[illegible]
		[illegible]	100	7.56	3.734	0.373		
4.	The ramp problem (Testing of hypotheses)	[illegible]	100	2.36	2.745	0.225	-2.66	[illegible]
			100	3.25	2.46[illegible]	0.249		
5.	The formulating questions problem (problem sensitivity)	[illegible]	100	3.19	[illegible].726	0.077	2.69	[illegible]
		[illegible]	100	6.67	3.373	0.3[illegible]		
6.	Mechanical reasoning ([illegible])	[illegible]	100	13.47	[illegible].417	[illegible]	2.6[illegible]	[illegible]
		[illegible]	1[illegible]	16.58	7.232	0.7[illegible]		

1	2	3	4	5	6	7	8	9
7.	Spelling (AU)	A	100	16.79	15.516	1.557	-3.93	**
		G	100	29.47	21.604	2.160		
8.	Sentences (AU)	A	100	3.53	4.933	0.493	-3.84	**
		G	100	6.73	6.725	0.673		
9.	Language usage (AU)	A	100	22.30	16.995	1.699	-4.60	**
		G	100	37.20	27.549	2.755		
10.	Group dependent/self sufficient (Q_2) (HSPQ)	A	100	10.92	2.665	0.267	3.50	**
		G	100	9.31	3.757	0.376		
11.	The worms problem (Testing of hypotheses)	A	100	1.95	1.623	0.162	-2.00	**
		G	100	2.40	1.563	0.156		
12.	Concrete thinking/Abstract thinking(B) (HSPQ)	A	100	5.38	1.745	0.175	-2.04	*
		G	100	6.71	6.279	0.628		
13.	Obedient/Assertive (E) (HSPQ)	A	100	9.28	2.796	0.280	2.35	*
		G	100	6.30	3.063	0.306		
14.	Shy/Adventurous (H) (HSPQ)	A	100	10.33	3.336	0.334	2.05	*
		G	100	9.42	3.367	0.337		

1	2	3	4	5	6	7	8	9
15.	The seed problem ([illegible] of hypotheses)	B	100	11.45	6.804	0.680	1.74	n.s.
		G	100	13.13	6.486	0.649		
16.	The flow of liquid through a tube problem (Testing of hypotheses)	B	100	3.25	1.901	0.190	0.0	n.s.
		G	100	3.25	2.057	0.206		
17.	The simple pendulum problem (Testing of hypotheses)	B	100	3.13	2.481	0.248	-1.64	n.s.
		G	100	3.71	2.532	0.253		
18.	The digital problem (permutations and combinations)	B	100	18.21	4.105	0.411	-0.36	n.s.
		G	100	18.41	3.686	0.369		
19.	The magic seed problem (permutations and combinations)	B	100	16.95	6.509	0.651	-0.94	n.s.
		G	100	17.70	5.962	0.596		
20.	Questions inviting wrong answers problem(Grasping the essence of the problem)	B	100	2.66	1.358	0.136	0.77	n.s.
		G	100	2.48	1.904	0.190		
21.	Intelligence	B	100	91.31	15.182	1.518	0.23	n.s.
		G	100	90.81	15.118	1.512		
22.	Abstract reasoning (A.R)	B	100	21.06	12.412	1.241	-1.[illegible]	n.s.
		G	100	21.70	10.486	1.049		

1	2	3	4	5	6	7	8	9
23.	Numerical ability ([illegible])	B	100	9.16	5.606	0.561	-0.37	n.s.
		G	100	9.48	6.686	0.669		
24.	Space relations ([illegible])	B	100	24.24	20.703	2.070	1.77	n.s.
		G	100	22.27	15.306	1.531		
25.	Verbal reasoning ([illegible])	B	100	11.31	6.761	0.676	0.05	n.s.
		G	100	11.27	5.603	0.560		
26.	Reserved/Outgoing ([illegible]) (HSPQ)	B	100	10.64	2.684	0.265	-1.92	n.s.
		G	100	11.73	3.768	0.377		
27.	Emotionally less stable/ Emotionally stable (C) (HSPQ)	B	100	10.66	2.664	0.266	0.78	n.s.
		G	100	10.36	2.773	0.277		
28.	Phlegmatic/Excitable ([illegible]) (HSPQ)	B	100	8.28	2.731	0.273	1.06	n.s.
		G	100	7.85	3.006	0.301		
29.	Serious/Heedless ([illegible]) (HSPQ)	B	100	7.34	2.545	0.255	-0.18	n.s.
		G	100	7.91	3.078	0.308		
30.	Expedient/Conscientious (G) (HSPQ)	B	100	12.62	4.062	0.406	0.09	n.s.
		G	100	12.57	3.791	0.380		

1	2	3	4	5	6	7	8	9
31.	Toughminded/Tenderminded (I) ([illegible])	[illegible]	100	10.42	2.682	[illegible]	-1.65	n.s.
		[illegible]	100	11.19	3.160	0.316		
32.	Zestful/Circumspect ([illegible]) ([illegible])	[illegible]	100	9.99	2.091	0.209	0.92	n.s.
		[illegible]	100	9.62	2.370	0.297		
33.	Secure/Insecure (O) ([illegible])	[illegible]	100	9.56	2.738	0.274	1.05	n.s.
		[illegible]	100	9.13	3.311	0.331		
34.	Uncontrolled/Self disciplined (Q_3) (E3F4)	[illegible]	100	10.07	2.668	0.267	1.16	n.s.
		[illegible]	100	9.53	3.647	0.365		
35.	Relaxed/Tense (Q_4) ([illegible])	[illegible]	100	9.01	3.132	0.313	-0.61	n.s.
		[illegible]	100	9.31	3.616	0.362		

** Significant at 0.01 level

* Significant at 0.05 level

n.s. Not significant

A word of caution is necessary while making judgement on sex differences because it is very necessary to identify the variables which really operate in a study sample : type of school, regional as well as cultural differences and the role of educational variables such as recency of curriculum, innovative methodology of instruction and availability of instructional and illustrative materials, preferably of the programmed variety. Using 't' test, significant sex differences on the various variables of the study was seen.

When the measures of twelve Piaget type tasks for both the sexes are compared, six 't' ratios have been found to be significant out of the twelve computed. It is interesting to note that out of the six significant ratios, five 't' ratios on the five problems, namely, The flow of liquid through a tube problem, The simple pendulum problem and The ramp problem of stating hypotheses, and The ramp problem and worms problem of Testing hypotheses have been found showing better performance on the part of the girls in comparison to boys. The boys have been found to be performing better than girls on 'The formulating questions problem'. No significant sex differences have been found on the following six problems : The seed problem of stating hypotheses, The flow of liquid through a tube problem and The simple pendulum problem of Testing of hypotheses, The digital problem and The magic seed problem of permutations and combinations and Questions inviting wrong answers problem (Grasping the essence of the problem).

Of the eight aptitude variables, only four : Mechanical reasoning, Spelling, Sentences and Language usage show significant sex differences. The first one favours boys and the last three, girls. Sex differences are not noticed on Abstract reasoning, Numerical ability, Space relations and Verbal reasoning. Significant sex difference was also not found on Intelligence quotient.

Of the fourteen variables of personality, only four dimensions : Concrete thinking - Abstract thinking, Obedient - Assertive, Shy-Adventurous and Group dependent - Self sufficient have been found to show significant sex differences. All the other ten personality variables : Reserved - Outgoing; Emotionally less stable - Emotionally stable; Phlegmatic - Excitable; Serious - Heedless; Expedient - Conscientious; Tough-minded - Tender-minded; Zestful-Circumspect; Secure - Insecure; Uncontrolled - Self disciplined; and Relaxed - Tense do not show any significant differences between the sexes.

.4 How are the abilities to set up and test hypotheses related to the various variables included in the study?

The product moment co-efficient of correlation were computed between the measures of the abilities of stating and testing hypotheses and the measures of the other variables such as age, intelligence, measures of aptitude, measures of personality in order to determine the relationship between them. The results in this regard have been presented in the table below :

Table No. 25

Correlations between Stating of Hypotheses and Testing of Hypotheses with the Other Variables Included in the Study

S.No.	Variables	Stating of Hypotheses	Testing of Hypotheses
1.	Age	444**	507**
2.	Permutations and Combinations (Total)	396**	373**
3.	Digital Problem	274**	329**
4.	Magic Seed Problem	362**	299**
5.	Questions Inviting Wrong Answers Problem (Grasping the Essence of the Problem)	394**	407**
6.	Verbal Reasoning	439**	291**
7.	Abstract Reasoning	429**	262**
8.	Spelling	344*	312**
9.	Language Usage	356**	288**
10.	Sentences	244**	223**
11.	Numerical Ability	282**	334**
12.	Space Relations	429**	299**
13.	Expedient/Conscientious (G)	265**	190**
14.	Reserved/Outgoing (A)	194**	215**
15.	Formulating Questions Problem (Problem Sensitivity)	291**	076
16.	Mechanical Reasoning	242**	120
17.	Concrete Thinking/Abstract Thinking (B)	176*	087
18.	Uncontrolled/Self Disciplined (Q_3)	187**	078
19.	Phlegmatic/Excitable (D)	-108	-165*
20.	I.Q.	089	091

S.No.	Variables	Stating of Hypotheses	Testing of Hypotheses
21.	Zestful/Circumspect (J)	033	$\bar{0}$14
22.	Serious/Heedless (F)	$\bar{0}$11	$\bar{0}$77
23.	Emotionally less stable / Emotionally more stable (C)	$\bar{0}$15	$\bar{0}$45
24.	Obedient/Assertive (E)	083	026
25.	Shy/Adventurous (H)	$\bar{0}$51	$\bar{0}$33
26.	Toughminded/Tenderminded (I)	036	$\bar{0}$17
27.	Secure/Insecure	$\bar{0}$26	$\bar{0}$30
28.	Group dependent/Self sufficient (Q_2)	$\bar{0}$12	$\bar{0}$36
29.	Relaxed/Tense (Q_4)	043	$\bar{0}$15

** Significant at 0.01 level

* Significant at 0.05 level

From the above table, it is clear that the both the measures of the ability to state hypotheses and test hypotheses are significantly related at 0.01 level with : Age, Permutations and combinations (Total), Digital problem, Magic seed problem, Questions inviting wrong answers problem (Grasping the essence of the problem), Verbal reasoning (DAT), Abstract reasoning (AR), Spelling, Language usage, Sentences, Numerical ability, Space relations, Expedient - Conscientious and Reserved - Outgoing. In addition, the measure of Stating hypotheses is significantly related with Formulating questions problem (Problem sensitivity), Mechanical reasoning and Uncontrolled - Self disciplined trait at 0.01 level and Concrete thinking - Abstract thinking trait at 0.05 level and the measure of Testing hypotheses is negatively significant at 0.05 level with

the Phlegmatic - Excitable trait of personality. Both the measures of Stating and Testing hypotheses are not found to be correlated with I.Q., Zestful - Circumspect, Serious - Heedless, Emotionally less stable - Emotionally stable, Obedient - Assertive, Shy - Adventurous, Toughminded - Tender-minded, Secure - Insecure, Group dependent - Self sufficient and Relaxed - Tense variables. In addition, the measure of Testing hypotheses is not found to be correlated with Formulating questions problem (Problem sensitivity), Mechanical reasoning, Concrete thinking - Abstract thinking and Uncontrolled - Self disciplined variables.

Q.5 What are the characteristic differences between the successful and unsuccessful problem solvers?

The adolescent pupils were classified as successful (top group) and unsuccessful (bottom group) problem solvers by arranging them (N = 200) according to the descending order of their scores on two aspects of formal reasoning : Stating of hypotheses and Testing of hypotheses. Taking top 25 per cent (N = 50) as successful problem solvers and bottom 25 per cent (N = 50) as unsuccessful problem solvers, the 't' ratios were computed between the two for Stating of hypotheses, Testing of hypotheses and the fourteen Personality factors. The results are presented in the following table :

Table No. 26

Mean, S.D., S_{E_D} and 't' values for the Top and Bottom Group on Stating of hypotheses, Testing of hypotheses and Fourteen Personality Factors

S.No.	Variable	Group	Mean	S.D.	S_{E_D}	t	Sig.
1.	Stating of hypotheses	Top	53.64	6.760	1.352	26.22	**
		Bottom	18.18				
2.	Testing of hypotheses	Top	19.08	1.72	0.344	45.81	**
		Bottom	3.32				
3.	Concrete thinking/ Abstract thinking	Top	6	5.82	0.2328	5	**
		Bottom	4.84				
4.	Uncontrolled/Self disciplined	Top	9.7	10.144	0.405	2.469	*
		Bottom	9.24				
5.	Relaxed/Tense	Top	6.26	9.542	0.3817	2.510	*
		Bottom	9.22				
6.	Reserved/Outgoing	Top	13.44	11.271	0.254	1.472	n.s.
		Bottom	10.12				

S.No.	Variable	Group	Mean	[illegible]	[illegible]	t	Sig.
7.	Emotionally less stable/ Emotionally stable	Top	10.24	117.87	4.714	-0.067	n.s.
		Bottom	10.56				
8.	Phlegmatic/Excitable	Top	7.54	76.010	3.040	0.366	n.s.
		Bottom	8.72				
9.	Obedient/Assertive	Top	8.52	61.816	3.272	0.048	n.s.
		Bottom	8.66				
10.	Serious/Heedless	Top	7.62	8.315	0.3326	1.683	n.s.
		Bottom	8.18				
11.	Expedient/Conscientious	Top	13.24	13.301	0.5320	0.374	n.s.
		Bottom	11.62				
12.	Shy/Adventurous	Top	10.06	10.770	0.430	0.15	n.s.
		Bottom	10.34				
13.	Toughminded/Tenderminded	Top	10.5	11.105	0.444	0.4504	n.s.
		Bottom	10.7				

S.No.	Variable	Group	Mean	Var.	SE	t	Sig.
14.	Zestful/Circumspect	Top	9.6	10.108	0.404	0.148	n.s.
		Bottom	9.66				
15.	Secure/Insecure	Top	9.62	157.24	4.14	0.053	n.s.
		Bottom	9.4				
16.	Group dependent/ Self sufficient	Top	9.7	10.538	0.421	1.032	n.s.
		Bottom	10.16				

** Significant at 0.01 level

* Significant at 0.05 level

n.s. Not significant

Of the sixteen 't' ratio's computed to find out if there are significant differences between successful (top group) and unsuccessful (bottom group) problem solvers, significant difference between the two were noticed on stating of hypotheses, Testing of hypotheses, Concrete thinking - Abstract thinking, Uncontrolled - Self disciplined and Relaxed - Tense variables. No significant difference between the two were found on variables : Reserved - Outgoing, Emotionally less stable - Emotionally stable, Phlegmatic - Excitable, Obedient - Assertive, Serious - Heedless, Expedient - Conscientious, Shy - Adventurous, Toughminded - Tenderminded, Zestful - Circumspect, Secure - Insecure and Group dependent - Self sufficient. From this it can be summarized, that, successful problem solvers are good hypotheses staters and testers, abstract thinkers, self disciplined and relaxed whereas the unsuccessful problem solvers are not good hypotheses staters and testers, concrete thinkers, uncontrolled and tense.

Summary of Findings

The over all impression got from the analysis and interpretation of the accumulated data are as follows :

1. Adolescent pupils are in a position to set-up hypotheses in all the age groups. However, the ability to state hypotheses show an increasing trend with age. The first hypotheses that Adolescent pupils are in a position to set up hypotheses in all the age groups stands tested.

2. The adolescent pupils are found to test the given hypothesis in all grades. The percentage of pupils operating at three levels (Below formal, Partially formal and Fully formal) both within the individual grade and across the three problems very widely. However, it can be concluded that the individual minds of the adolescent pupils have not yet become fully experimental which in other words means that adolescent thought as a whole within the context of the study is a mixture of concrete thought (below formal) and developing formal thought (partially formal) which has yet to attain its equilibrium. The second hypotheses 'The given hypothesis is tested successfully in all the age groups has been empirically verified.

3. Of the twelve Piaget type tasks, six tasks showed significant difference between boys and girls, five tasks favouring girls and one, boys, contrary to an earlier study by Sandhu (1980) on a rural (Punjab) sample where he found boys performing better than girls on the Piaget-type tasks. The contrary result of the present study can be attributed to the fact that this sample was drawn from an urban (Mysore) area where girls are given equal opportunities as boys and they compete with boys in all fields of life. Curiously enough in this sample too, in conformity with the commonly held belief, the boys showed a mechanical bent of mind and girls showed their mastery over boys in linguistics, though no significant differences were observed between the sexes on I.Q., Abstract reasoning ability (as measured by DAT), Numerical ability, Space relations and Verbal reasoning. Boys and girls differed from each other in respect

of four personality variables. Boys are found to be self-sufficient, concrete thinkers, assertive and adventurous. Where as girls are Group dependent, Abstract thinkers, Obedient and Shy. The third hypothesis i.e., boys and girls perform equally well on Piaget type tasks and aptitude tests and no significant differences exists between them on personality variables has been confirmed only partially.

4. Of the twenty nine co-efficients of correlation computed between the Exclusion of variables (Stating and Testing of hypotheses) and other variables included in the study, both Stating and Testing of hypotheses ability were found to be positively significantly related at 0.01 level with variables: Age, Permutations and Combinations, Digital problem, Magic seed problem, Grasping the essence of the problem, Verbal reasoning, Abstract reasoning, Spelling, Language usage, Sentences, Numerical ability, Space relations, Expedient - Conscientious and Reserved - Outgoing. Stating of hypotheses was related significantly at 0.01 level with Problem sensitivity, Mechanical reasoning and Uncontrolled - Self disciplined dimension of personality and at 0.05 level with Concrete thinking - Abstract thinking dimension of personality. Testing of hypotheses is found to be related significantly with phlegmatic - Excitable trait of personality at 0.01 level. The fourth hypotheses: There exists a significant relationship between the measure of Exclusion of variables with the measures of : Age, I.Q., Aptitude (DAT), Personality, Permutations and combinations, Problem sensitivity and Grasping the essence of the problem is partially confirmed.

5. Significant differences between successful and unsuccessful problem solvers are found to exist on Stating of hypotheses, Testing of hypotheses and Concrete thinking - Abstract thinking, Uncontrolled - Self disciplined and Relaxed - Tense dimension of personality. The successful problem solvers are good hypotheses staters and testers and are abstract thinkers, Self disciplined and Relaxed whereas the unsuccessful problem solvers are not good hypotheses starters and testers and are concrete thinkers, Uncontrolled and Tense. This result again partially confirms the fifth hypotheses : There exists significant differences between successful and unsuccessful problem solvers on : Stating of hypotheses, Testing of hypotheses and Personality traits.

Lastly, the main summary of the present work is given in the eighth chapter.

CHAPTER VII

REVISITING NONP EFFECT

AS

OBSERVED DURING PROBLEM SOLVING

CHAPTER VII

REVALIDATING HUMP EFFECT
AS
OBSERVED DURING PROBLEM SOLVING

Introduction

Some researches on reasoning have revealed some very interesting phenomena. One such being, 'errors' which was noticed and highlighted by Jean Piaget which he observed while standardizing an intelligence test at Paris in 1920. He found that similar types of errors were commited by children of the same age group. In contrast to the general view that the number of errors diminishes as age increases, it is found that during the formal operational stage there is a spurt and the number of errors commited by the adolescents suffer a 'hump'. This peculiar phenomena was also encountered by M.Vaidya much later in 1975 while he tried to investigate the thought processes of the adolescents. He raised certain issues concerning this odd phenomenon :

> Is it the case of an adolescent playing with figures thoughtlessly or arbitrarily in the hope of being favoured with good luck? Is it the case of lack of seriousness on his part? Is it a case of being caught between the horns of a dilemma and getting mux? Is it the case of hot chase trying hard to choose in haphazard directions as if in the manner of closing in on the problem? Does it illustrate that mastery of a thought process is through a path: uphill, thorny and often erratic? Or does the adolescent regress as if on an adventurous Piagetian journey

> during which he is trying hard to educate out himself, thinking that the right path to concept development lies in flourishing on experimental failures, or a problem solving situation in which either understanding suffers a dip or errors a hump? Alternatively, is it a fact of rubbing his schemes of thought wrongly, especially when he has personal reservations about his self acquired knowledge in contrast to school learning which does not set right his firmly held self centred thoughts? Lastly, is it the case that he chooses to be very romantic in his computations when confronted with a problem situation leading to a chaos?

These quests needed further clarification and were referred to Prof. J.S. Bruner for comments.

Bruner (1976) stated :

> The type of error that you refer to, which we speak of as growth error, is one which a growing child tries out a new strategy although it is not well developed and uses it in place of an older one which has been working well. It is errors of this sort which suggest to me the venturesomeness of learning during this early period, the human beings are willing to shift to a less certain and more powerful strategy, before they have it under control, in preference to one which is safe, sound and dull.

Again this phenomenon of 'hump effect' was observed by Sandhu and Vaidya (1978). They found that the dominant errors (shared by more than 20 per cent of the pupils) tend to increase with age before their frequency finally fell. According to them, it occurs when the pupils are at the transitory stage of mental development midway between concrete stage and the formal stage, that is, at a point where, the distinction between the two, temporarily speaking becomes too difficult to discern. Incidentally, L.Lanaskar (1979) and M.Mathur (1981) while tackling a particular scheme of thought

highly relevant to this study also encountered this phenomenon which was mentioned without any firm explanation. ?.?.Senchu (1980) too encountered this phenomenon in his doctoral study on three dimensions of adolescent thought i.e., ratio and proportion (R/P), grasping the essence of the problem (G.E.) and space visualization (SV). Similar data are not easily available. Quite a few who did encounter this phenomenon missed mentioning it. They are David Elkind (1977), Lovell and Ogilliva (1977), Martorano (1977), Piaget and Inhelder (1977) and ?.L.Dominowski and Duncan (1977). Lastly, the relevant data on Indian children within the general confines of the study are reproduced below which hint at the possible existence of 'Hump Effect'.

Illustrations of the Phenomenon

Table No. 27

Data of Various Studies Grade-wise

S. No.	Author and Year	Description of the problem/task/process/dimension of thought	Grade					
			VI	VII	VIII	IX	X	XI
1	2	3	4	5	6	7	8	9
I.	N.Vaidya 1975	Percentage of Pupils Committing Errors in the Problem and Process :						
1.		What is the height of Mohan?	40	57.2	25	10	0	
2.		Generalization to algebraic symbol	47.5	42.5	67.5	72	55	
3.		What is the total distance when the man goes four times around the rectangle?	12.5	27.5	17.5	12.5	2.5	

1	2	3	4	5	6	7	8	9
4		Suppose a donkey has two horns. How many horns in all have eight donkeys?	27.5	20	42.5	52.5	37.5	
5.		Beakers problem	67.5	85	72.5	65	57.5	
6.		What is the combined real depth of the fish when seen from above as well as from below?	12.5	25	20	47.5	5	
7.		Proposing tests problem	35	47.5	62.5	27.5	2.5	
II.	B. Vaidya and [illegible] Sandhu 1976	Mean scores on the problem :						
8.		Weight problem	1.45	.53	2.25	3.13	3.20	
9.		Digital problem (combinatorial)	2.67	2.45	1.35	5.40	7.78	
10.		Formulating questions problem	5.67	9.13	7.40	9.65	11.48	
11		Fish problem	.05	.28	2.56	2.90	4.90	
III.	[illegible] Sanzakar 1979	Mean scores on problems of stating of hypotheses :						
12.		The rod problem			4.9	7.2	8.3	7.6
13.		The handkerchief problem			4.5	7.4	6.2	6.7
14.		The flow of water through a glass tube			5.6	6.9	6.2	6.7
15		The pendulum problem			3.6	6.5	6.4	6.3

1	2	3	4	5	6	7	8	9
		Mean Scores on problems of Testing of Hypotheses :						
16.		The rod problem			3.6	4.6	4.3	4.6
17.		The handkerchief problem			5.9	6.8	6.1	6.9
18.		The flow of water through a glass tube			5.8	6.9	6.2	6.9
19.		The pendulum problem			5.7	6.0	6.0	6.8
IV.	[illegible] Sandhu 1980	Mean Scores on the Dimension of Adolescent Thought :						
20.		Ratio and proportion	.23	.59	.89	1.09	1.97	
21.		Space visualization	5.69	7.97	8.25	10.45	9.67	
22.		Grasping the essence of the problem	.67	1.00	.96	.96	1.39	
V.	R. Mathur 1981	Mean Scores on problems of Stating of Hypotheses :						
23.		Flow of water through a tube	3.8	4.5	8.1	7.8	6.2	7.6
24.		Simple pendulum	4.5	4.6	7.7	6.0	7.5	8.1
25.		The ramp problem	3.1	3.5	7.0	7.0	6.4	7.2
26.		The seed problem	5.0	6.1	7.2	6.8	6.7	8.9

1	2	3	4	5	6	7	8	9
		Mean Scores on problems of Testing of Hypotheses :						
27.		Flow of water through a tube	3.3	4.3	5.0	[illegible]	5.2	5.5
28.		Simple pendulum problem	3.4	4.3	3.7	[illegible]	4.9	5.3
29.		The ramp problem	3.5	4.0	3.1	4.6	4.6	4.9
		Mean Scores of the problems in Some Interesting and Funny Questions :						
30		Using 2-digit at a time 1(a) (digital problem)	8.6	17.4	15.5	6.6	18.5	20.0
31.		Using 3-digit at a time 1(b) (digital problem)	.60	3.1	4.7	3.1	6.4	9.2
32.		Using 4-digit at a time 1(c) (digital problem)	6.2	3.6	4.0	3.6	4.2	4.0
33.		Inviting wrong answers	3.1	3.6	3.6	3.0	3.1	1.8
34.		Magic seed problem	10.3	14.2	19.1	16.1	22.7	23.6
35.		Worms problem	3.9	4.5	4.2	4.4	5.0	4.7
		Mean Scores of the errors committed on Problem :						
36.		Cycle problem	.6	.9	.4	1.0	.5	.8
37		Magic seed (resting points)	.6	1.8	5.5	3.8	3.5	4.4

1	2	4	5	6	7	8
VI. Padmini, R.I. 1982	Mean Scores on Problems of Setting of Hypotheses :					
38	The flow of liquid through a tube problem	5.92	7.70	9.07	8.77	9.87
39.	The simple pendulum problem	5.00	6.55	7.95	6.27	6.97
40.	The ramp problem	3.70	9.12	8.42	7.77	9.97
41.	The seed problem	7.00	12.32	12.92	9.05	20.00
	Mean Scores on Testing of Hypotheses :					
42.	The flow of liquid through a tube problem	2.37	2.45	2.75	4.57	4.10
43	The simple pendulum problem	1.32	3.45	2.90	4.67	4.55
44.	The worms problem	1.57	2.22	2.05	2.42	2.60
	Mean Scores on Permutations and Combinations					
45	The magic seeds problem	14.22	16.92	19.15	15.47	21.05
	Mean Scores on Problem Sensitivity					
46	Formulating questions problem	5.75	6.92	8.77	5.75	12.45
	Mean Scores on Grasping the Essence of the problem :					
47	Questions inviting wrong answers problem	1.02	2.45	2.47	2.60	4.30

1	2	3	4	5	6	7	8	9
		Mean Scores of the Testing Points in :						
48.		Digital problem	3.5	3.6	3.3	1.6	2.4	
49.		Magic seed problem	9.5	4.1	5.3	3.1	3.1	
*50		Formulating questions problem	1.7	1.2	0.6	0.8	0.5	

* Graphically illustrated

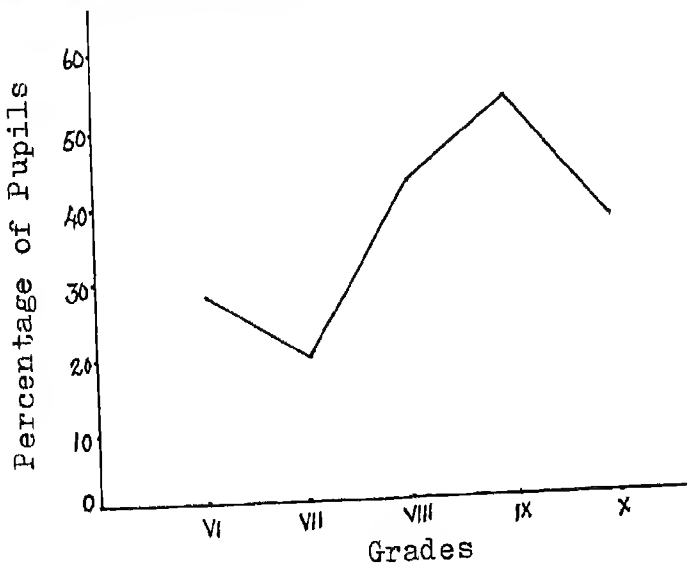


Fig.55
Hump of the Dominant Error on the Problem at Serial No.4

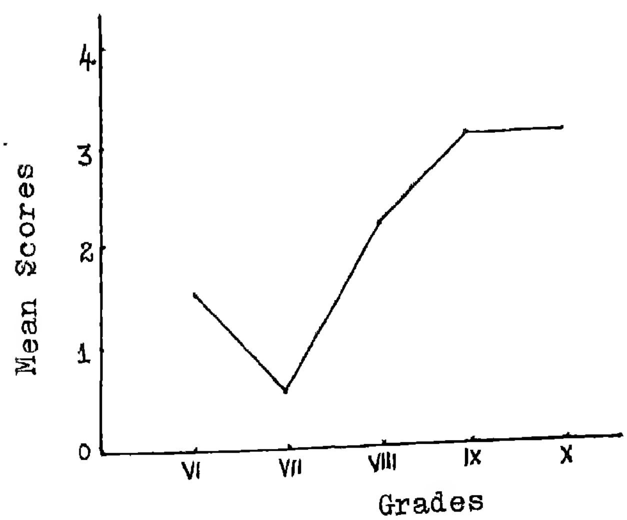


Fig.56
Hump of the Mean Scores on the Problem at Serial No.8

Contd.

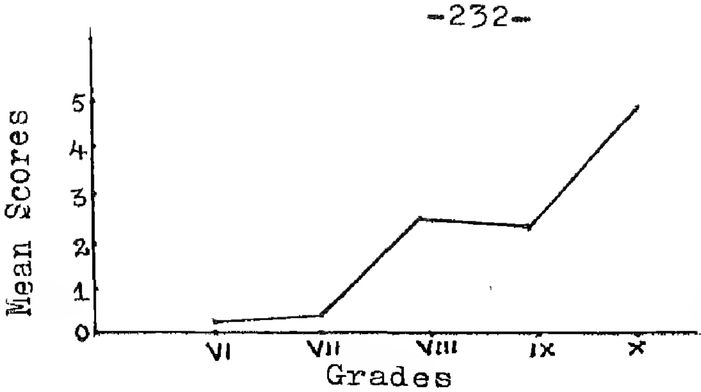


Fig.57
Hump of the Mean Scores on the Problem at Serial No.11

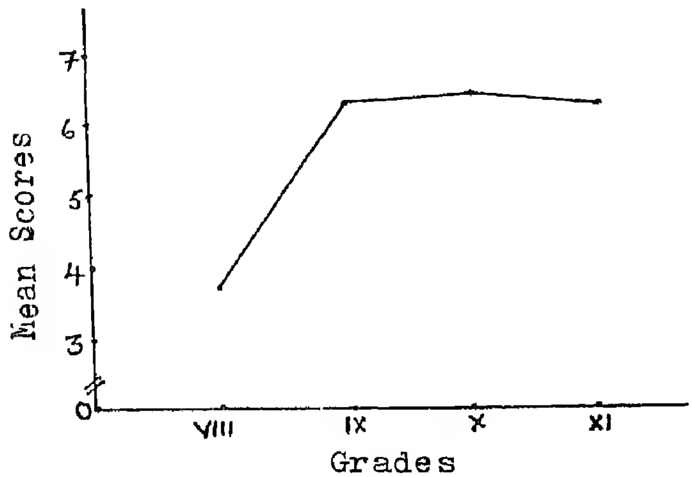


Fig.58
Hump of the Mean Scores on the Problem at Serial No.15

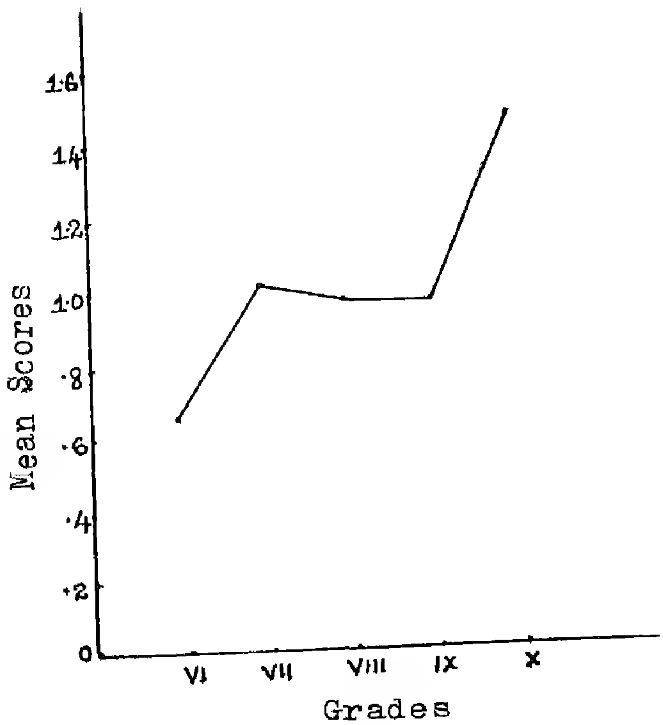


Fig.59
Hump of the Mean Scores on the Dimension of Adolescent Thought at Serial No.22

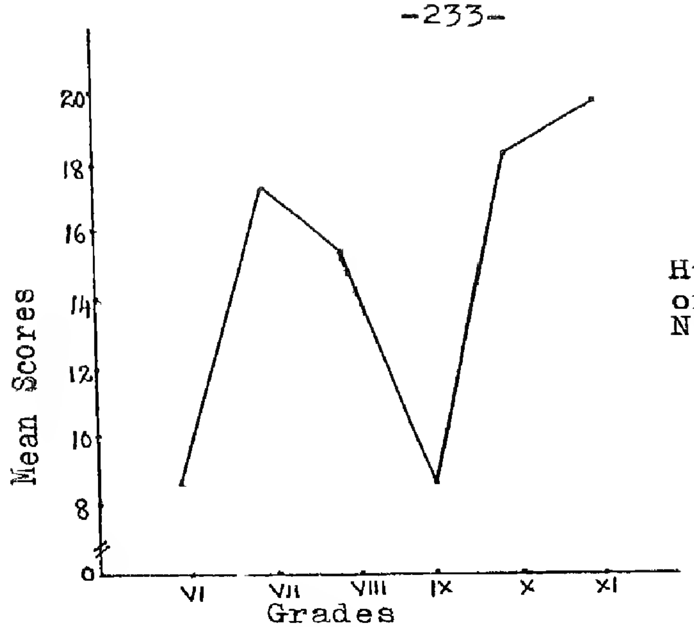


Fig.60
Hump of the Mean Scores on the Problem at Serial No.30

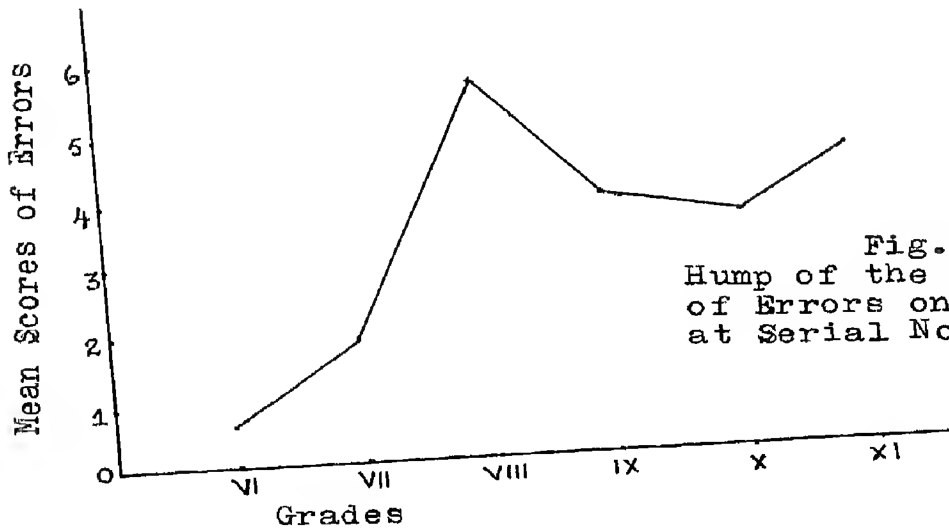


Fig.61
Hump of the Mean Scores of Errors on the Problem at Serial No.37

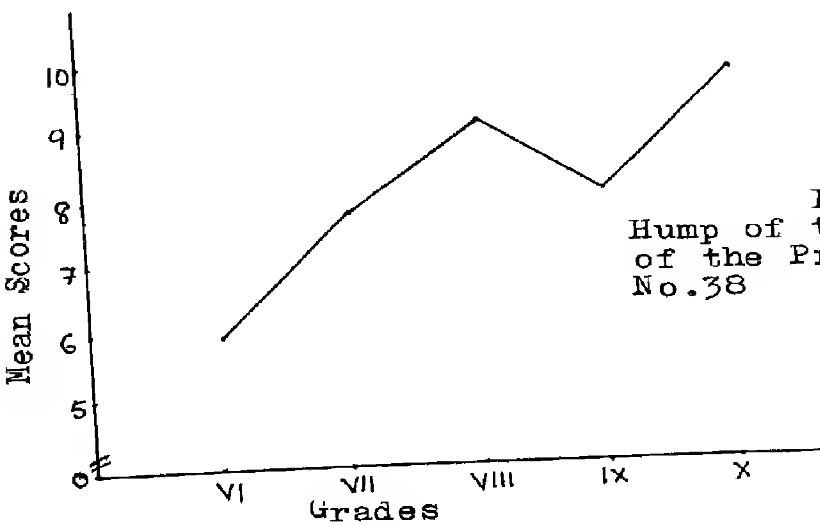


Fig.62
Hump of the Mean Scores of the Problem at Serial No.38

Fig.63
Hump of the Mean Scores of the Problem at Serial No.43

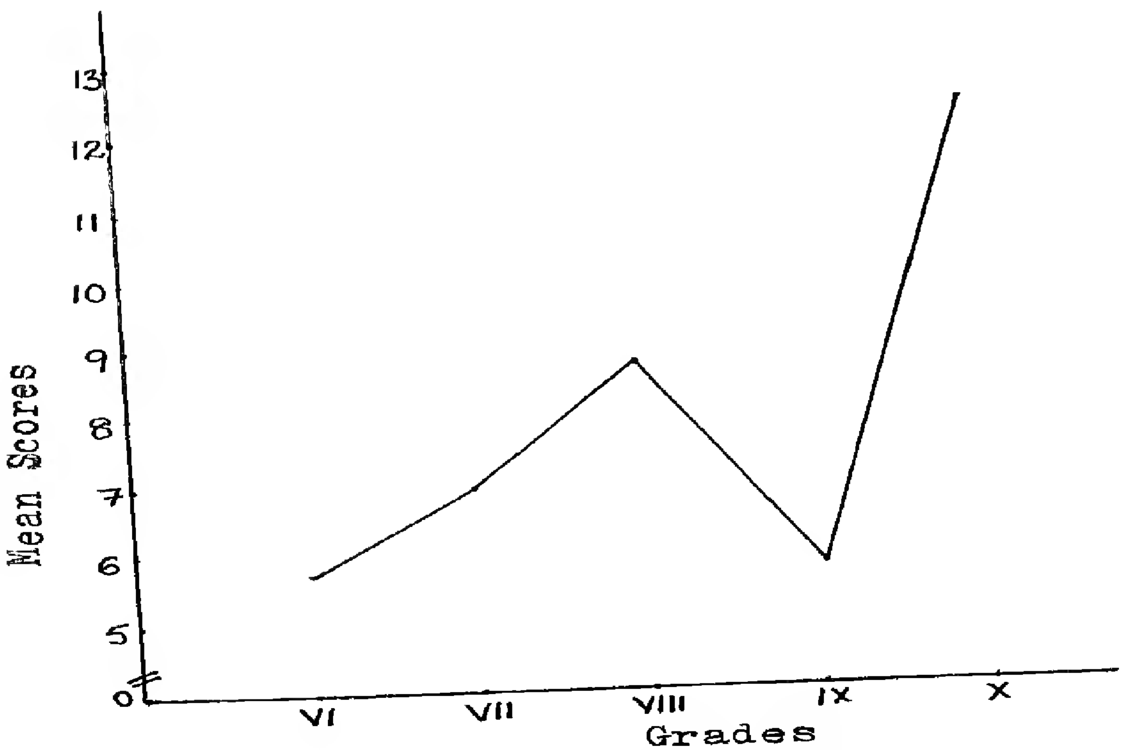


Fig.64
Hump of the Mean Scores of the Problem at Serial No.45

Fig.65
Hump of the Mean Scores of the Problem at Serial No.46

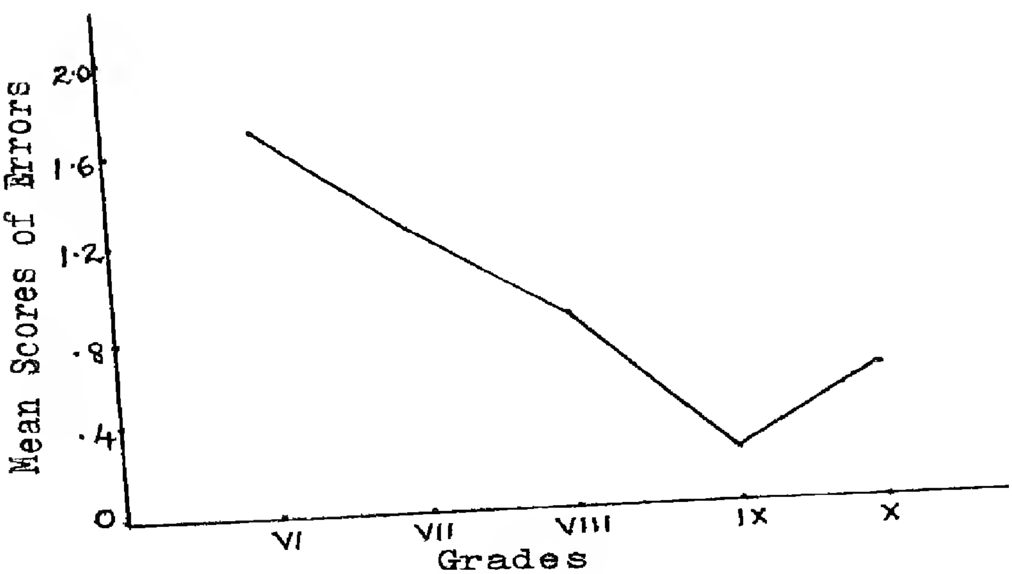


Fig.66
Hump of the Mean Scores of Errors of the Problem at Serial No.50

Concluding Statement

The phenomenon of hump effect has not been studied specifically in this study. Equally speaking, when a search is made for similar studies in research literature, one more or less draws a blank. Hence no firm explanation is available for this phenomenon which like electromagnetism may be of temporary character. In this study, it has appeared in tasks inhering the following schemes of thought missed earlier by Vaidya and Sandhu, namely, Stating hypotheses, Testing hypotheses, Permutations and combinations (similar to combinatorial grouping), Problem sensitivity and other subtle contexts. So, the parameters of this phenomenon stand a bit broadened because of this study. Hence, if effort is made to investigate this phenomenon within the contexts of intelligence testing (developmental as well as psychometric), convergent and divergent problem solving including creativity as usually tested and the psychological structure verious school subjects, each taken separately, this when hypothesized may appear prominently in its undisguised form. More specifically, taking an entire view of this unusual phenomenon, Vaidya and Sandhu have suggested the following hypotheses for intensive investigation in their paper on : Hump Effect as Observed During Problem Solving. These are :

1. Hump Effect appears when thought process moves from a lower stage to a higher stage, the most fruitful area for attack being the transitory period between any pair of the two succeeding stages.

2. It appears at all ages, choice of problems being the determining factor, among pupils at different levels of intellectual development when new concepts are under development. It may appear in sex difference studies relating in achievement and intellectual deterioration among adults later on.

3. It is suspected that it may equally appear in the above mentioned contexts when :
   (i) Longitudinal studies on thought processes are undertaken.
   (ii) when thought processes are accelerated under controlled conditions.

4. It is further suspected that every concept in each individual suffers a hump before it finally settles down in his mind.

When seen from the view point of educating children, it is necessary to make an observation. It is that, in their day to day teaching, teachers should not always insist on right answers alone. The incorrect answers equally tell a different story. For example, how far a given idea may go in its application. Or what is its mileage? Hump effect, if it exists at all, comes handy to children because it is their firm concern to develop concepts firmly which have 'broad measure of generality' in a medium where learning from errors is not disdained upon. Instead, it becomes a respectable educational activity accepted by all on secure theoretical grounds as well. Consequently, brakes will apply automatically if the teaching goes too fast in the face of this hypothesized construct if eventually confirmed in the later studies.

CHAPTER VIII

SUMMARY, EDUCATIONAL IMPLICATIONS AND SUGGESTIONS

CHAPTER VIII

SUMMARY

Introduction

It is a strange paradox that 'explosion of knowledge' of today has given man unlimited power on one hand and on the other, has opened out a possibility of it being used for his total annihilation. This is an age of 'Space travel' as well as of 'Atomic energy'. Life is no more simple as it was, it has become challenging and complex. Over the centuries, philosophers and later, the psychologists tried to study and explain human behaviour and the human mind. They succeeded only partially and failed to give a total picture of the working of the human mind. Educationists and psychologists, today have taken a keen interest in studying and understanding the various thinking processes underlying the working of the mind. The 20th century psychology believes that "...the life of the mind is a dynamic reality, intelligence a real and constructive activity" (Modgil, 1974). The late Prof. Jean Piaget (1896-1980) who, by his intensive research over the years right until death, wrote a large number of articles, papers, monographs and books and gave the world the famous 'Piagetian theory' epitomized in the 'Geneva school' which explains the development of cognition qualitatively from birth until the first 20 years of life. Though

his theory was slow to be accepted, it now stands acclaimed all over the world, giving food for thought to researchers outside Geneva. According to him, intelligence develops in four stages : Sensory motor (0-2 years), Pre-logical (2-7 years), Concrete (7-11 years) and Formal (11-15 years). Recently he had hinted at the possibility of a fifth stage which covers the period from 15 to 20 years after considering factors like aptitude variations and commitment to individual careers against the back drop of now less prominent general intellectual development. The first stage begins with the capacity for a few reflexes and ends when language and other symbolic ways of representing the world first appear. In the second stage, the child's thinking is dominated by his perception. Here, the thinking is generally intuitive and transductive. In the third stage, though the thinking, to a large extent, resembles adult thought, child, however, fails to think abstractly or hypothetically. In the fourth stage, the thinking is highly sophisticated and it involves : hypothetico-deductive operations, proportional logic and combinatorial systems. The ultimate equilibrium of intelligence is found in this stage, which develops during adolescence. Adolescence, in contrast to the trouble and turmoil view, is regarded by Piaget as the most exhilarating and productive time of life. The development of abstract reasoning among adolescents is more urgent today than ever before, to help them tackle the complex situations, man is confronted with at present. Abstract thinking is essential for learning

science as one is required to manipulate ideas and possibilities in the mind. The present study was undertaken with a view to investigate the thinking processes the adolescents adopt for solving problems, in particular, the stating and, testing of hypotheses as inhered in the Scheme of Exclusion of Variables which is a basic character of the formal thought.

Past Work

As one goes through the research literature, it is found that researches conducted outside Geneva still deal more with concrete operational stage than formal stage of cognitive development. The formal operational thought in relation to factors like : cultural, social and personality traits of adolescents is still to be investigated to get a clear picture. With regard to the mathematical structure of adolescent thought, only very recently a handful of studies have appeared. The few studies that have direct bearing on the present study are those of : Yroke (1961), Beard (1962), Vaidya (1964), Karze and Karze (1971), Rengel and Buell (1972), Kiern (1973), Somerville (1974), Karplus, Karplus, Formisano and Paulsen (1975), Lonzy and Cox (1975), Vaidya (1975), Joyce (1977), Crewal (1978), Saneskar (1979), Sandhu (1980) and Mathur (1981). Some important studies which have indirect bearing on this problem as they investigated different aspects of formal reasoning are those of Peel (1960), Lovell, K. (1961), Bruner, J.S., Goodnow, J.J. & Austin, G.A. (1962), Lovell, K. & Butterworth, J.E. (1966), Karplus, R. & Karplus, E.F. (1970),

Munzer, Morrison & Davey (1972), Renner, J.W. & Stafford, D.G. (1972), Lawson, A.E. (1974), Abramowitz, S. (1975), Griffin, [illegible] (1975), Lawson, A.E. & Renner, J.W. (1975), Linn & Levine (1976), Cortorano, [illegible] (1977), Cantu, L.L. & Herron, J.D. (1978), Baker, [illegible] et al (1979), Saizeda, V. (1981). However, even when all these studies are consolidated together, they fail to scretch the various schemes of thought developing during adolescence as enunciated by Piaget in his vast research project. When the findings of various individual studies are aggregated and reflected upon, the following statements of the tentative type can be safely made.

(i) Majority of the normal adolescents operate at the concrete operational level.

(ii) The adolescents who are in a position to state hypotheses are not necessarily in a position to test the stated hypotheses.

(iii) The ability to attack the problems positively increased with age and grade.

(iv) The study of physics requires more of formal thought than chemistry and biology.

(v) In the development of concept, mental-age and grade are more important than chronological age.

(vi) Significant relationship exists between academic achievement and creativity.

(vii) Concrete operational period merges with the beginnings of formal thought at possibly 13 or 14 years of age 2 or 3 years later than the transitional period of Piaget.

(viii) It is only rarely that 'average to bright' junior school children reached the level of formal thought.

(ix) The relevant cognitive content in the learner's cognitive structure facilitated the new learning in an increasing non-linear manner.

(x) Children go through various stages of development with each level a necessary prelude to the following level.

(xi) There is a possibility of the existence of a fifth stage called 'problem finding stage' among adults. And, the fourth stage, called the 'problem solving stage' is a necessary condition for the development of the fifth stage. But all problem solvers are not problem finders.

Aims and Objectives

The study aimed at investigating the following :

1. To investigate adolescent thought through a short, reliable and valid test instrument incorporating Piaget type tasks.

2. To determine the relationships between the scores on certain aspects of exclusion of variables and some outside variables : Age, Sex, Intelligence, Personality characteristics and Aptitude.

3. To analyse the structure of exclusion of variables along with three other aspects of formal thought (Permutations and combinations, Problem sensitivity and Grasping the essence of the problem).

4. To determine the characteristics of successful and unsuccessful problem solvers on Piaget-type tasks.

5. To point out the main educational implications based upon the findings of the study.

Hypotheses

It was proposed to test the following hypotheses in this study :

1. Adolescent pupils are in a position to set up hypotheses in all age groups.

2. The given hypothesis is tested successfully in all the age groups.

3. Boys and girls do not differ significantly in performance on Piaget type tasks, aptitude tests and personality variables.

4. There exists a significant relationship between the measures of exclusion of variables (Setting and Testing of hypotheses) with the measures of : Age, I.Q., Aptitude (DAT), Personality (H.S.Q.), Permutations and combinations, Problem sensitivity and Grasping the essence of the problem.

5. There exist significant differences between successful and unsuccessful problem solvers.

Questions Posed

The present study, being a qualitative one, also enabled to raise the following questions which were answered by rearranging the data as demanded by them. These questions were :

1. How many hypotheses can an adolescent pupil state at the various ages?

2. What is the incidence of formal reasoning among the present group of adolescent pupils taken in this study?

3. What are the sex-differences on Piaget-type tasks and other variables included in this study?

4. How are the abilities to set up and test hypotheses related to the various variables included in this study?

5. What are the characteristic differences between the successful and unsuccessful problem solvers?

Method of Procedure

Sample

The sample consisted of 200 students (100 boys and 100 girls) drawn randomly, out of a sample of 600 students, from four Middle and High schools of Urban area (Mysore), belonging to 10+, 11+, 12+, 13+, and 14+ years age levels studying in grades VI, VII, VIII, IX and X respectively. Each grade represented equal number of boys and girls. All the schools were private institutions following the syllabus prescribed by the Karnataka Secondary Board of Education and the medium of instruction of the sample was English.

Tests Developed

Twelve Piaget type tasks out of were finally chosen by the investigator. They were written in the questionnaire form. The tasks were not administered enmasse

but they were presented in three separate questionnaire of four, three and five tasks each as follows :

Table No. 28

Twelve Piaget Type Tasks and Their Codes

Q. No.	Questionnaire	Piaget Type Tasks	Code
I.	Stating of Hypotheses		
1.		The flow of liquid through a tube problem	T_1P_1([illegible])
2.		The simple pendulum problem	T_1P_2([illegible])
3.		The ramp problem	T_1P_3([illegible])
4.		The seed problem	T_1P_4([illegible])
II.	Testing of Hypotheses		
1.		The flow of liquid through a tube problem	T_2P_1(TOM)
2.		The simple pendulum problem	T_2P_2(TOM)
3.		The ramp problem	T_2P_3(TOM)
III.	Some Interesting and Funny Questions		
1.		Digital problem	DP([illegible])
2.		Formulating questions problem	FQP
3.		Questions inviting wrong answers problem	[illegible]
4.		Magic seeds problem	MSP(PAC)
5.		The worms problem	T_3P_5(TOM)

Other Standardised Tests Used

1. Culture Fair (Free) Intelligence Test (Scale II Form A) - Cattell and Cattell.

2. High School Personality Questionnaire (HSPQ) - Cattell and Cattell.

3. Aptitude Tests (DAT)
   (i) Abstract Reasoning
   (ii) Verbal Reasoning
   (iii) Numerical Ability
   (iv) Mechanical Reasoning
   (v) Space Relations; and
   (vi) Language Usage.

Statistical Treatment of Data

The growth of 'Exclusion of variables during adolescence', that is, the 'Stating and Testing of hypotheses' ability of adolescent boys and girls (N = 200) was studied in relation to other factors like Intelligence (Non-verbal), Personality (HSPQ), Aptitude (DAT), Permutations and Combinations, Problem Sensitivity and Grasping the essence of the problem (Schemes of adolescent thought). In all, there were thirty nine variables whose data were computed, using the programme marginals with all statistics from Statistical Package for the Social Sciences (Nie et al, 1970) through 'DCM-1077 Computer' at Computronics India, New Delhi.

The statistics computed were main, standard deviation and 't' value sex-wise for all the variables for the whole sample as well as for sub samples to test the various hypotheses

stated earlier. The mathematical structures of the various tasks and tests were also determined.

Main Findings

1. The four problems of stating of hypotheses have attracted a wide spectrum of thought.

2. When it comes to stating hypotheses to a particular problem on consideration in every possible form, adolescent pupils appear to be generous in stating them as judged by the total frequency of the hypotheses emitted. However, most of the adolescent pupils miss most of the hypotheses as judged by means alone regardless of the individual hypotheses. This suggests the following conclusion that, the hypotheses are set up the way the problem is seen by the individual adolescent pupil.

3. Whereas the mean performance on this variable (stating hypotheses) increases with grade and indirectly with chronological age, the variability of the various groups tends to become more or less homogenous at the closing grade of the study which, however, is reversed when it comes to testing hypotheses. Despite this oddity, the mean performance on testing hypotheses shows an increasing trend with grade.

4. Sex differences with occasional fluctuations exist favouring girls, across grades as well as across problems of testing of hypotheses, contrary to the findings of Vaidya and Sandhu. Whereas for the problems of permutations and combinations, no significant sex difference is noticed.

5. In case of problems of permutations and combinations, the mean performance with minor fluctuations here and

there and except a major fluctuation in grade 11 for magic seed problem, increases with grade. However, all the adolescent pupils of this study were not in a position to exhaust all the possible combinations.

6. Ability to formulate novel questions with minor fluctuations was found to increase with grade.

7. The grade means of problem sensitivity revealed that boys asked more questions than girls in all grades except 11.

8. Despite divergence in aims and objectives, modes of presentation and nature of sample of the various studies in the Piagetian context, it is not only seen that the major part of adolescent thought is characterized by erratic behaviour, pre-logical thought and concrete behaviour, but also a sort of parallelism in sample responses exists when the quantitative thought developed logically tends to attain identity in thought. Except the maintenance of sequence of development, the Piagetian age ranges have no relevance as such. It is precisely for this reason that a given problem or a part of the problem is solved successfully not only within individual grades but also across the grades as well.

9. Majority of the adolescent pupils are attracted more by the content rather than the form of the problem.

10. When the fifteen variables of the Piaget type tasks were factor analysed for the whole sample (N = 200) using the Principal component method and rotated by Varimax, four factors appeared :

Table No. 29

Psychological Nomenclature Eigen Values, Percent of Variance and Cumulative Percentage of the Four Factors of the Fifteen Variables of the Piaget Type Tasks

S. No.	Order of Factors	Psychological Nomenclature	Eigen values	Percen -tage Variance	Cumulative Percentage
1.	First Factor	Stating Hypotheses	5.765	38.6	38.6
2.	Second Factor	Testing Hypotheses	2.111	14.1	52.6
3.	Third Factor	Permutations and Combinations	1.077	11.5	64.2
4.	Fourth Factor	Problem Sensitivity	1.077	7.2	71.3

When these four factors were subjected to Cores test, the last two factors were judged insignificant.

11. The successful problem solvers are good hypotheses staters and testers, abstract thinkers, self disciplined and relaxed where as the unsuccessful problem solvers are not good hypotheses staters and testers, concrete thinkers uncontrolled and tense.

12. Of the twelve Piaget type tasks, six were found to show significant sex differences. Five favouring girls and one, boys. Boys showed a mechanical bent of mind and girls showed mastery in linguistics. Boys were found to have self sufficient, concrete thinking, assertive and adventurous personality traits and girls were found to have group dependent, abstract thinking, obedient and shy personality traits.

13. Age was found to be significantly correlated with both (Stating and Testing of hypotheses) the measures of exclusion of variables. Only certain traits of personality correlated with the measures of exclusion of variables and except a few, most of the aptitude

tests were found to significantly correlated with the measures of exclusion of variables. Where as formulating questions problem was correlated significantly only with the measure of Stating of Hypotheses, permutations and combinations and grasping the essence of the problem was found to be significantly correlated with both the measures of exclusion of variables.

14. Considering the entire sample (N=200) and the entire tests and tests (n=39), using the Principal component method (Varimax rotation, the following twelve factors appeared:

Table No. 30

Psychological Nomenclature, Eigen Values, Percent of Variance and Cumulative Percentage of the Twelve Factors of the Thirty Nine Variables of the Study

[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Variance	[illegible]
1.	First Factor	Language Factor	8.640	22.2	22.2
2.	Second Factor	Exclusion of Variables (Testing Hypotheses)	2.807	7.2	29.4
3.	Third Factor	Exclusion of Variables (Stating Hypotheses)	2.595	6.7	36.0
4.	Fourth Factor	Super Ego Strength	2.186	5.6	41.6
5.	Fifth Factor	Group Factor of Personality (Dominance, Guilt Proneness, Ego Strength)	1.887	4.6	46.5
6.	Sixth Factor	Permutations and Combinations	1.809	4.6	51.1
7.	Seventh Factor	Mechanical Reasoning	1.665	4.3	55.4
8.	Eighth Factor	Self Sufficiency	1.263	3.2	58.6
9.	Ninth Factor	Age	1.164	3.0	61.6
10.	Tenth Factor	Parmia	1.468	2.9	64.5
11.	Eleventh Factor	Ego Strength	1.068	2.7	67.3
12.	Twelfth Factor	Intelligence	1.013	2.6	69.9

EDUCATIONAL IMPLICATIONS

It is a pity that a highly theoretical system as the one propounded by Piaget, has little to say on education. The reason for this appears to be that, Piaget set to himself a different problem to solve and thereby founded a new branch of knowledge called Experimental epistemology. Having worked extensively with Piaget type problems, Prof. Robert Karplus and his workers have suggested three distinct type of lessons, namely, Exploratory, Inventory and Discovery. In Australia, Prof. K.F.Collis suggested a Solo taxonomy for classifying whereby the various levels of thinking could be identified in several branches of knowledge and consequently, adapted to day to day classroom situation. In The Essential Piaget, Howard . Gruber and J. Jacques Voneche, have also pointed out the entire educational implication arising out of Piaget's work. They say some what as follows :

1. He emphasizes the importance of activity in the growth of intelligence.

2. He explores in depth the growth of the child's thinking in relation to certain universals in the contents of human experiences such as the nature of objects, space, time, motion, chance, causality, moral responsibility and social awareness.

3. He proposes that certain underlying pervasive logico-mathematical structures are found repeatedly in these diverse areas : Taos (Respect for the individual artisan), Paris (Pleasures of discussion), Athens (The Socratic method) and Eldorado (Both the

teacher and the pupil participate in the processes of concept formation, application and discovery) are the four models worthy of considering while schematising the use of materials and exercises on the one hand and the type of social relationships on the other.

Within the context of this study, three educational implications appear :

1. There is lot of concrete thought as well as pre-logical thought present among the adolescent pupils. It is possible to educate them out through appropriate methodology where pupils are compelled to see the same situation from others points of view or in different contexts. For example, within the context of this study, it may be possible to train pupils in raising appropriate questions on problem sensitivity problem.

2. It is possible to classify pupil responses on a rating scale. Through appropriate training, it should be possible to raise their levels of thinking to higher levels as well. Dump effect, of course, has been encountered in this study. If long term planning is done in methodology of instruction, it may become feasible to accelerate their thinking substantially.

3. It is the job of school to promote efficient thinking among its pupils. Specifically speaking, it is possible to design short learning (Experimental) loops based upon specific problems and concepts for pupils of average and below average ability. The experimental loop, according to J.C.Powell appears when they :

   1. Plan and execute a series of activities designed to initiate learning. Either the children or the teacher may do the designing of the activity, but

the children must do the planning and execution of the plan.

2. Do not know the solution to the problem posed by the activity before commencement of the task.

3. Can generate several alternative ways of attempting to complete the task.

4. Find at least one solution which successfully completes the requirements of the task.

5. Understand the task well enough upon completion that they can replicate and/or transfer success.

Thinking along these lines is surely to result in balanced instruction of science suiting differentiated abilities with little stress on mechanical acquisition of knowledge, for, teaching is not telling, but also directing too.

PROBLEMS FOR FURTHER RESEARCH

Any investigation answers only a few questions. It can not be complete in itself. And, when the human thinking process, a highly complex phenomenon, is investigated, the conclusions drawn remain purely hypothetical. So, the need for further studies arise. Following are some of the suggestions for further research :

1. This study may be replicated at three levels of : intelligence, socio-economic-status and achievement.

2. As only certain personality factors were found to correlate with the adolescent thinking in this study, a more comprehensive study may be undertaken to study their relationship.

3. Research may be conducted to know how many schemes of thought are really fundamental in the fields of physics, chemistry, biology and environmental science.

4. Hump effect observed during adolescence in this study can be either confirmed or refuted by undertaking an investigation using more tests.

5. A study may be conducted to see whether it is possible to accelerate the thought processes of adolescents through training programmes. Experimental studies may be taken up to evaluate the effectiveness of such training programmes.

6. A properly planned longitudinal study may be taken up to see the growth of cognitive development during adolescence.

7. It is known that combinativity, reversibility, associativity and identity available are seen to be generalized at the formal stage within the Genevan context. It is precisely for this reason that there is the emergence of operational schemata like combinatorial, proportional, mechanical equilibria, correlation and probability etc. appear on the onset of formal thought. Each of them needs to be investigated at depth. In the present study, only one scheme of thought defined loosely, has been investigated. Similar ones from the actual context in science and mathematics can be visualised and experimented upon. Examples are : Potential, Work and Function etc. Laws like, Ohms law and Inverse square law can also be considered as regards their acquisition when pupils are allowed to play with relevant experimental materials.

8. It is very necessary now to investigate factor analytically the emergence of various schemes of

thought simultaneously age-wise as well as sex-wise through out the entire period of adolescence. Even investigation of the same at the higher age ranges wont be futile because, it is hypothesised, we may see the convergence of two approaches, namely, psychometric and developmental merging during the fifth stage whose possibility was hinted at by Prof. Piaget before his death.

[illegible]

REFERENCES

Abramowitz, M. Adolescent Understanding of Proportionality, Ph.D. thesis, Stanford University, Also Personal Communication, 1975(a).

Adams, J.A. and Dominowski, R.L. Short-term Memory for Motor Responses, Quoted from Motor Learning and Retention by Jack A. Adams in Fundamentals and Applications of Learning by Melvin H. Marx and Marion E. Bunch, MacMillan Publishing Company Inc, New York, 1977.

Alexander, W.P. Intelligence, Concrete and Abstract, British Journal of Psychological Monograph Supplements, 19, 177, 1935.

Ambartsumi, et al. In All India Survey of Achievement in Mathematics, NCERT, New Delhi, 1970.

Arlin, P.K. Cognitive Development in Adulthood: A Fifth Stage? Development Psychology, 11, 602-606, 1975.

Arons, A.B. Cultivating the Capacity for Formal Reasoning: Objectives Procedure in an Introductory Physical Science Course, American Journal of Physics, Vol.44, No.9, September, 1976.

Atkin, Myron J. A Study of Formulating and Suggesting Tests for Hypotheses in Elementary School Science Learning, Science Education, 42: 414-422, 1958.

Ausubel, D.P. Theory and Problems of Adolescent Development, Grune, 1954.

Andy, Richard J. The Development of Hypotheses Testing and Correlational Reasoning, Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching, 50th, Cincinnati, Ohio, March 22-24, 1977.

Bady, Richard. Logical Reasoning Abilities in Male High School Science Students, Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching, 50th Cincinnati, Ohio, March 22-24, 1977.

Bailey, Ralph J. The Difficulty Level of Certain Science Concepts, Science Education, Vol. 25: 84-89, 1941.

Baker, ... How Students in a Secondary Modern School Induce Scientific Principles from Scientific Experiments. Unpublished M.Ed. Thesis, Birmingham University, 1956.

Bantista, A.D. The Relationship Between Intellectual Levels and Achievement in the Comprehension of Concepts Classified According to Scheme Derived from Piagetian Model, 1975

Bart, W.M. The Factor Structure of Formal Operations, British Journal of Educational Psychology, 41, 70-77, 1971.

Bart, W.M. Construction and Validation of Formal Reasoning Instruments, Psy. Rep., 30, 663-70, 1972.

Bartlett, F.C. Thinking : An Experimental Study, George Allen Unwin Ltd., London, 1958.

Bates, G.C. More on the Problem of Physics Enrolment, Science Teacher, Vol.42, p.29 and 30, October, 1975.

Bawa, Gurubans Singh. The Effect of Training and Intelligence on Formal Operation Thought (Stating and Testing Hypotheses) M.A.(Education) Dissertation, Punjabi University, Patiala, Punjab, 1981.

Bayley, N. Data on the Growth of Intelligence Between 16 and 21 years, Genetic Psychology, 90, 3-15, 1957.

Beard, R.M. Children's Reasoning, Mathematics Teaching, 21, 33-39, 1962.

Bennet, et al. [illegible]. The Psychological Corporation, Manasayan, New Delhi, 1969 (New York, 1959).

Berzonsky, M.D., Lombardo, T.P. and Ondrako, M.A. Changes in Logical Thinking as a Function of Induced Disequilibrium, Journal of Genetic Psychology 92, 255-60, 1975.

Blake, Anthony J.D. Measurement of Level of Intellectual Development in Australian Secondary Schools : A Report to the Education Research and Development Committee, Riverina College of Advanced Education, Wagga Wagga, New South Wales (Australia), 1977.

Blasi, A. and Hoeffel, E.C. Adolescence and Formal Operations, Human Development, 17, 344-363, 1974.

Bloom, B.S. Stability and Change in Human Characteristics. Wiley, 1964.

Bolton, Neil. The Psychology of Thinking, Methuen and Co.Ltd., London, 1972.

Braine, M.D.S. Piaget on Reasoning : A Methodological Critique and Alternative Proposals, Mon. Soc. Res. Child. Dev.,27, 41-62, 1962.

Brainerd, C.J. Judgements and Explanations as Criteria for the Presence of Cognitive Structures, Psychological Bulletin, 79, 172-179(b), 1973.

Brainerd, C.J. Stage, Structure and Developmental Theory. In G. Steiner (Ed), The Psychology of the Twentieth Century. Munich : Kindler, 1976(a).

Brainerd, C.J. Piaget's Theory of Intelligence, Prentice-Hall Inc. Englewood Cliffs, New Jersey, 1978.

Brown, W. and Stephenson, W. A Test of the Theory of Two Factors, British Journal of Psychology, 23,352-370, 1933.

Brown, W. and Thomson, G.H. The Essentials of Mental Measurement, Cambridge University Press, Cambridge, 1921.

Bruner, J.S. Personal Communication, 1976.

Bruner, J.S., Goodnow J.J. and Austin G.A. A Study of Thinking, New York, Science Editions Inc., New York, 1962.

Burt, C. The Factors of the Mind : An Introduction to Factor Analysis in Psychology, Macmillan, New York, 1941.

Burt, C. The Structure of the Mind : A Review of the Results of Factor Analysis, British Journal of Educational Psychology, 19, 176-199, 1949.

Buswell, G.T. Patterns of Thinking in Solving Problems, University of California Press, Berkeley, 1956.

Campbell, Sarah F.(Ed.). Piaget Sampler. An Introduction to Jean Piaget Through His Own Words, John Wiley and Son, Inc., New York, U.S.A., 1976.

Cantu, L.L. and Herron Dudley. Concrete and Formal Piagetian Stages and Science Concept Attainment, Journal of Research in Science Teaching, Vol.15, Issue 2, March 1978.

Case, R. Learning and Intellectual Development, Final Report, California University, Berkeley, Institute of Human Learning, 15th July, 1974.

Case, R. Structures and Strictures : Some Functional Limitations on the Course of Cognitive Growth, Cognitive Psychology, 6, 544-573, 1974.

Case, D. and Collinson, J.M. The Development of Formal Thinking in Verbal Comprehension, British Journal of Psychology, 32, 103-111, 1962.

Cattell, R.B. Factor Analysis, Harper and Bros, New York, 1952.

Cattell, R.B. and Cattell, A.K.S. Culture Fair Intelligence Test - Scale 2, Form A, The Psycho - Centre, New Delhi, 1964.

Cattell, R.B. and Cattell, A.K.S. Handbook for the Individual or Group Culture Fair Intelligence Test - Scale 2, The Psycho Centre, New Delhi, 1960.

Cattell, R.B. and Cattell, M.D. Handbook for the Jr - Sr High School Personality Questionnaire (HSPQ), The Psycho-Centre, New Delhi, 1976.

Chiappeta, E.L. A Review of Piagetian Studies Relevant to Science Instruction at the Secondary and College Level, Science Education, 60, 253-261, 1976.

Clayton V. and Overton, W.F. Concrete and Formal Thought Process in Young Adulthood and Old Age, International Journal of Aging and Human Development, 7, 3, 237-245, 1976.

Cohen J. and C. Hansel. The Idea of Independence, British Journal of Psychology, 46, 178-90, 1955.

Comber L.C. and Reeves John P. Science Education in Nineteen Different Countries, UNESCO.

Copper, Dennis A. and Others. The Relation between Formal Operations and a Possible Fifth Stage of Cognitive Development, Developmental Psychology, 13, 5, 517-518, Sept., 1977.

Covington, M.V., Crutchfield, R.S., Davies, L.B. and Olton, R.M. The Productive Thinking Program, Columbus, Ohio: Charles E. Merril Co., Columbus, Ohio, 1974.

Cowan, Philip A. Piaget : With Feeling. Cognitive, Social and Emotional Dimensions, Holt, Rinehart and Winston, New York, U.S.A., 1978.

Dale, L.G. The Growth of Systematic Thinking : Replication and Analysis of Piaget's First Chemical Experiment, Australian Journal of Psychology, 22, 277-286, 1970.

Danier, G.M. Concrete and Formal Thinking Among Adolescent Children of Average Ability, Unpublished M.A. Thesis, Birmingham University, 1964.

Danner, Fred W. and Day, Mary Carol. Eliciting Formal Operation, Child Development, 48, 4, 1600-6, December 1977.

Dasen, Pierre R.(Ed. Piagetian Psychology. Cross-Cultural Contributions. Gardner Press, Inc., New York, 1977.

DeLuca, Fredrick P. Measurement of Logical Thinking : An Electronic Equivalent of Piaget's First Chemical Experiment, Journal of Research in Science Teaching, 14, 6, 539-44, Nov., 1977.

DeLemos, M.M. The Development of Conservation in Aboriginal Children, International Journal of Psychology, 4, 255-269, 1969.

DeLuca, F.P. Application of Cluster Analysis to the Study of Piagetian Stages of Intellectual Development, Journal of Research in Science Teaching, Vol.18, No.1, pp.51-59,1981.

Dettrick, Graham W.A. Study of the Structure of Piagetian Logical and Infralogical Grouping Within the Concrete Operational Period, Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching, 48th Los Angles, California, March, 1975.

Donaldson, Margret. A Study of Children's Thinking, Tavistock Publications, 1963.

Donaldson, M. <u>Children's Mind</u>, William Collins Sons and Co. Ltd., Glasgow, Great Britain, 1978.

Dockerty, [illegible] Indentifying Concrete and Formal Operational Children, (In Press), 1974.

Dewey, John. <u>How We Think</u>, D.C. Health & Co., London, 1910.

Dominowski, R.L. Problem Solving, in <u>Fundamentals and Applications of Learning</u> Ibid, 1967.

Donaldson, M. A Study of Children's Thinking, Tavistock, London, 1963.

Dudek, S.Z. et al. Relationship of Piaget Measures to Standard Intelligence and Motor Scales, Perception and Motor Skills, 29, 351-362, 1969.

Dulit, E. Adolescent Thinking a la Piaget: The Formal Stage, Journal of Youth and Adolescence 1, 4, 281-301, 1972.

Duncan, C.P. Response Heirachies in Problem Solving, in <u>Fundamentals and Applications of Learning</u>, Ibid, 1967.

Dunlop, David Living Stone. An Information Theoretic Analysis of Classification Sorting and Cognition by Ninth Grade. Children within a Piagetian Setting, Ph.D. Dissertation, University of Pittsburgh, 1973 (University Microfilms order No. 74-2081).

Dunlop, David L. and Fazio, Frank. A Study of Abstract Preferences in Problem Solving Tasks and their Relationship to Abstract Ability and Formal Thought, Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching, 48th Los Angles, California, March 17-20, 1975.

Dunlop, David L. and Fazio, Frank. A Comparison of Student Preferences and Actual Performance in Problem Solving Tasks within a Piagetian Setting. Paper Presented at the Annual Meeting of National Association for Research in Science Teaching 50th, Cincinnati, Ohio, March 22-24, 1977.

Dyrli, Edward O. An Investigation into the Development of Combinatorial Mechanism Characteristic of Formal Reasoning Through Experimental Problem Situations with Sixth-Grade Students, Unpublished doctoral dissertation, Indiana University, Bloomington, 1967.

Elkind, D. Quantity Conceptions in College Students, Journal of Social Psychology, 57, 459-465, 1962.

Elacouney, [illegible] The Visual Perception of Space, British Journal of Psychological Monograph Supplements, 20, 89, 1935.

Emerey, W. The Status of Certain Probability Concepts and Combinatorial Abilities of High School Biology Students and the Effect of Genetics Instruction on These Cognitive Characteristics, 1973.

Encyclopaedia Britannica, Inc. William Benton, Publisher, 1943-1973, Helen Hemingway Benton, Publisher, 1973-1974, Chicago, U.S.A., 1979.

Ennis, R.H., Finkelstein, M., Smith, E. and Wilson, N. Conditional Logic and Children, Cornell Critical Thinking Readiness Project, Phase-II-C, Final Report, Cornell University, Ithaca, New York, 1969.

Ennis, R.H. Children's Ability to Handle Piaget's Propositional Logic : Conceptual Critique, Review of Educational Research, 45, 1-41, 1975.

Eysenck, H.J. *The Structure and Measurement of Intelligence.* Springer - Verlag, Berlin Heindelberg, New York, 1979.

Fjellman, J.S. Methods of Investigating Cognitive Development of Children in Rural Kenya : Some Kamba Results, Paper Originally Presented at the University of East Africa Social Science Council Conference, University College, Nairobi, Kenya, Dec. 1969.

Flavell, J.H. *The Developmental Psychology of Piaget.* D.Van Nostrand Company Inc. USA, 1963.

Floyd, Ann (Ed). *Cognitive Development in the School Years.* Croom Helm, London, in Association with the Open University Press, London, 1979.

Fuller, R.G., Karplus, R. and Lawson A.E. Can Physics Develop Reasoning? Physics Today, 30(2): 23-28, 1977.

Gagne, R.M. The Learning of Principles (Chapter 6, In *Analysis of Concept Learning* - Edited by Klausmeier and Harris Academic Press, New York and London, 1966.

Garrett, H.E. *Statistics in Psychology and Education.* Vakils, Feffer and Simons Ltd., Ninth Indian Reprint, 1979.

Geeslin, W.E. An Analysis of Content Structure and Cognitive Structure in the Context of a Probability Unit, Paper Presented at the Annual Meeting of the National Council of Teachers of Mathematics, Atlantic City, New Jersey. April, 1974.

Germain, J.G. et al. The Personality of the Child and the Utilization of Operative Thought, Enfance, 4-5, 399-405, 1976.

Ghatala, Lizabith S. The Cognitive Operations Specified in the Model Paper Presented at the Annual Convention of the American Psychological Association, 81st, Montreal, Canada, 27-31, August, 1973.

Glaser, R. and Resnick, L.B. Instructional Psychology, In P.H. Mussen and M. Rosenzweig (Eds), Annual Review of psychology, Palo Alto, CA. Annual Review, 1972.

Grant, Rosalie Kay. Relationships between Concrete and Formal Operational Physics Concepts and the Intellectual Levels of High School Students, M.Ed. Dissertation, University of Oklahoma, 1976.

Gray, William M. Test of Logical Thinking (Dayton University, Ohio) Sponsored by: National Center for Educational Research and Development, Washington D.C., Regional Research Program, September, 1973.

Graybill, L.C. A Study of Sex Differences in the Transition from Concrete to Formal Thinking Patterns, Diss. Abst., 34, 7, 3613 A - 4477 A, (3988-A), 1974.

Grewal, Avinash. A Study of Relationship between Hypotheses - Testing Ability in Science and Creativity, Studies in Science and Mathematics Education, An International Research Journal, Vol.1, 1978.

Gruen, G.E. Note on Conservation : Methodological and Definitional Consideration, Child Development, 37, 977-983, 1966.

Griffiths, D.H. The Study of the Cognitive Development of Science Students in Introductory Level Courses, 1973.

Griffiths, David H. Physics Teaching : Does it Hinder Intellectual Development? American Journal of Physics, 44, 1, 81-85, Jan. 1976.

Gruber, H.E. and Voneche J.J. The Essential Piaget, Routledge and Kegan Paul Ltd., London, 1977.

Guilford, J.P. Psychometric Methods, McGraw - Hill Book Co., New York, 1936.

Guilford, J.P. Human Abilities, Psychological Review, 47, 367-393, 1940.

Guilford, J.P. The Structure of Intellect, Psychological Bulletin, 53, 267-293, 1956.

Gumrele, Frances G. A Study of the Development in Logical Judgements in Science of Successful and Unsuccessful Problem Solvers in Grades Four Through Nine, Unpublished Doctoral Dissertation, University of Alabama, Tuscaloosa, 1967.

Guttman, Louis. A Basis for Scaling Qualitative Data, American Sociological Review, 9, 139-150, 1944.

Hale, J.P. An Investigation of Two Formal Operational Schemata in Adolescents Enrolled in The ISCS Classrooms of Three Selected Teachers, 1972.

Harman, H.H. Modern Factor Analysis, The University of Chicago Press, Chicago, 1960.

Harman, H.H. Modern Factor Analysis, The University of Chicago Press, Chicago, 1960.

Hatab, A. The Definition and Measurement by Verbal Methods of the Ability to Think Critically, M.A. Thesis, Institute of Education, London, 1964.

Hatano, G. A Developmental Approach to Concept Formation : A Review of Neo-Piagetian Learning Experiments, Dokkyo University Bulletin of Liberal Arts and Education, 5, 59-76, 1971.

Hathway, [illegible] The Unique Contribution of Piagetian Measurement to Diagnosis, Prognosis and Research of Children's Mental Development, 1975. In Sohan and Celia Modgil (Ed).
[illegible]
Publisher Company, London, 1976.

Heidbreder, E. Problem Solving in Children and Adults, Journal of Genetic Psychology, Vol.35, 1928.

Higgins, [illegible] and Gaite, A.J. Elusiveness of Formal Operational Thought in Adolescents, Proceedings of 79th Annual Convention of the American Psychological Association, Washington D.C., 1971.

Hill, [illegible] A Study of Logical Abilities in Children (Doctoral Dissertation, Stanford University, 1961) Dissertation Abstracts, 21, 3359, 1961. (University Microfilms No.61-1229).

Holt, John. How Children Fail, Pitman Publishing Corporation, New York, October, 1965.

Holzinger, K.J. Statistical Methods for Students in Education. Ginn and Co., Boston, 1928.

Holzinger, K.J. and Harman, H.H. Comparison of Two Factorial Analyses, Psychometrika, 3, 45-60, 1938.

Hooper, F.H., Goldman, J.A., Storck, P.A. and Burke, A.M. Stage Sequence and Correspondence in Piagetian Theory : A Review of the Middle - Childhood Period, In Research Relating to Children, Bulletin 28, Washington D.C. U.S. Printing Office, 1971.

Hotelling, Harold. Analysis of a Complex of Statistical Variables into Principal Components, Journal of Educational Psychology, 24, 417-41, 498-520, 1933.

Howe, A.C. Formal Operational Thought and the High School Science Curriculum. Paper Presented at the National Association for Research in Science Teaching, Annual Meeting, Chicago, 1974.

Howe, Ann C. and Janice Mierzwa, Promoting the Development of Logical Thinking in the Classroom, Journal of Research in Science Teaching, 14(5) : 467-472, September, 1977.

Hughes, M.M. A Four Year Longitudinal Study of the Growth of Logical Thinking in a Group of Secondary Modern School Boys, M.Ed. Thesis, University of Leeds, 1965.

Hull, Cooke, Kaufmann and Kasanin, Quoted from the abridged account given in the <u>Selected Readings on the Learning Process</u> by Theodore L. Harris and Wilson E. Schwahn, Oxford University Press, New York, 1961.

Humphrey, G. <u>Directed Thinking</u>, Dodd, Mead and Company, New York, 1948.

Hyram, G.H. An Experiment in Developing Critical Thinking in Children, Journal of Experimental Education, 26, 125-132, 1979.

Inhelder, B. and Chipman, H.H.(Eds), Zwingmann Chipmann (Co.-Ed.) <u>Piaget and His School</u>, Springer-Verlang, New York Inc. U.S.A., 1976.

Inhelder, B. and Piaget J. <u>The Growth of Logical Thinking : From Childhood to Adolescence</u>, (Parsons, A. & Milgram, S., trans), Basic Books Inc. New York, 1958.

Inhelder, B. and Sinclair H. <u>Learning Cognitive Structures</u>, In P.H.Mussen., J.Langer, and M.Covington (Eds), Trends and Issues in Developmental Psychology, Holt, Rinehart, & Winston, New York, 1969.

Inhelder, B., Sinclair H. and Bovet, M. Learning and the Development of Cognition. Routledge and Kegan Paul Ltd., London, 1974.

Jackson, S. The Growth of Logical Thinking in Normal and Sub-normal Children. British Journal of Educational Psychology, 35, 255-258, 1965.

Jain S.C. A Study of Problem Solving Behaviour in Physics Among Certain Groups of Adolescent Pupils, Ph.D. Thesis, (to be submitted) University of Rajasthan, Jaipur, India, 1982.

Joshi, J.N. The Development of Algebraic Concepts During Secondary School Years, Ph.D. Thesis. Punjab University, Chandigarh, 1970.

Joshi, J.N. Piagetian Concept of Time and Motion, An Empirical Validation, M.Ed. Dissertation, Punjab University, Chandigarh, 1974.

Joyce, L.K. A Study of Formal Reasoning in Elementary Education Majors, Science Education, 61 (2) : 153-158, 1977.

Juraschek. The Performance of Prospective Teachers on Certain Piagetian Tasks, Diss. Abst. International, 35, 9, 5969A.

Juraschek, W.A. and Grady. Format Variation on Equilibrium in the Balance, Journal of Research in Science Teaching, Volume 18, No.1, pp. 47-49, 1981.

Kanankar, Leela. A Study on the Exclusion of Variables During Adolescence, M.Ed. Dissertation, University of Rajasthan, Jaipur, India, 1979.

Karplus, R. & Arons, A.B. Implication of Accumulating Data on Levels of Intellectual Development, American Journal of Physics, 44, 4, 396, 1976.

Karplus, R. et al. Intellectual Development Beyond Elementary School IV Ratio : The Influence of Cognitive Style Lawrence Hall of Science University of California, Berkeley, California, 1974.

Karplus, E.F. and Karplus, R. Intellectual Development Beyond Elementary School I : Deductive Logic, School Science and Mathematics, 70, 398-406, 1970.

Karplus, R., Karplus E. Formisano M. and Paulsen A. Proportional Reasoning and Control of Variables in Seven Countries, Advancing Education Through Science Oriented Program, Report ID - 25, Lawrence Hall of Science, Berkeley, 1975.

Karplus, R. and Peterson, R.W. Intellectual Development Beyond Elementary School II : Ratio a Survey, School Science and Mathematics, 70 (9), 813-820, 1970.

Kates, S.L. and Yudin, L.W. Concept Attainment and Memory, Journal of Educational Psychology, 55, 103-9, 1964.

Keating, Daniel P. Precocious Cognitive Development at the Level of Formal Operations, Ph.D. Dissertation, The Johns Hopkins University, National Science Foundation, Washington D.C., 1973.

Kelley, T.L. Crossroads in Mind of Man, Stanford University Press, Stanford, California, 1928.

Khun, D. Relation of Two Piageting Stage Transitions of I.Q. Developmental Psychology, 12,2, 157-161, 1976.

Kidder, F. Richard, Investigation of Nine, Eleven and Thirteen Year Old Children's Comprehension of Euclidean Transformation, Paper Presented at the Annual Meeting of the National Council of Teachers of Mathematics, Atlantic City, New Jersey, 1974.

King, W.H. The Development of Scientific Concepts in Children, Human Development, Ira F. Gordon (Editor) Scott, Foresman and Company, Chicago, 1965.

Kiekts, H.J. Proportional and Combinatorial Reasoning in Two Cultures, Journal of Research in Science Teaching, Vol.16, No.5 pp. 439-443, 1979.

Knott, R. The Development of Scientific Concepts in Pupils of the First Two Years of a Secondary School, Personal Communication, 1974.

Kolodiy, G. The Cognitive Development of High School and College Science Students, Journal of College Science Teaching, 20-22, 1975.

Kolodiy, George Oleh. Cognitive Development and Science Teaching, Journal of Research in Science Teaching, 14(1): 21-26 January, 1977.

Kyle, T. An Investigation of the Thought Processes of a Group of 14 year olds During the Solving of Scientific Problems, M.Ed. Thesis, Glasgow, 1950.

Lawson, A.E. Relationships of Concrete and Formal Operational Science Subject Matter and the Developmental Level of the Learner, 1974.

Lawson, A.E. The Development and Validation of a Classroom Test of Formal Reasoning, Journal of Research in Science Teaching, Vol.15 No.1, pp.11-24, 1978.

Lawson, A.E. and Blake A.J.D. Concrete and Formal Thinking Abilities in High School Biology Students as Measured by Three Separate Instruments, Journal of Research in Science Teaching, 13, 3, 227-235, 1976.

Lawson, A.E. and Renner, J.W. Relationship of Science Subject Matter and Developmental Levels of Learner, Journal of Research in Science Teaching, 12, 347-358, 1975 (b).

Lawson, A.E. and Wollman, W.T. Encouraging the Transition from Concrete to Formal Cognitive Functioning An Experiment, Journal of Research in Science Teaching, 13, 413-430, 1976.

Lang, [illegible] How Difficult are some Concepts of Physics, The Australian Science Teachers Journal, Vol.18 No.1, 59-67 March, 1972.

Lengel, R.A. and Buell, R.R. Exclusion of Irrelevant Factors (The Pendulum Problem), Science Education, Vol.56, Issue No.1, Jan-Mar., 1972.

Lee L.C. The Concomitant Development of Cognitive and Moral Modes of Thought. A Test of Selected Deductions of Piaget's Theory, 1971.

Lepper, [illegible] and Phillips, D.G. Logical Thinking in Seventh, Eighth and Ninth Grade Students, Paper Presented at the 43rd Annual Meeting of National Association for Research in Science Teaching, Minneapolis, Minnesota, March, 1970.

Levine, D.I. and Linn, M.C. Scientific Reasoning Ability in Adolescence Theoretical View Points and Educational Implications, Journal of Research in Science Teaching, Vol.14 No.4, pp.371-384, 1977.

Lewis, William Rosdolph, The Influence of Age, Sex and School Size upon the Development of Formal Operational Thought, Dissertation Abstract, Vol. 33, 3, pp.554A, 1972.

Linn, M.C. and Levine, D.I. Adolescent Reasoning : The Development of the Ability to Control Variables, Advancing Education Through Science Oriented Programs Report PSC-9. Lawrence Hall of Science, Berkeley, 1976.

Linn, M.C. and Thier, H.D. The Effect of Experimental Science on the Development of Logical Thinking in Children, Journal of Research in Science Teaching, 12, 49-62, 1975.

Little, Audrey. A Longitudinal Study of Cognitive Development in Young Children, Child Development, 43, 3, 1024, 34, Sept., 1972.

Lovell, K. Follow up Study of Inhelder and Piaget's : The Growth of Logical Thinking, British Journal of Psychology 52, 143-53, 1961.

Lovell, K. and Butterworth, J.B. Abilities Underlying the Understanding of Proportionality, Mathematics Teaching, 36, 5-9, 1966.

Lovell, K. and Ogilvie, E. Conservation of Substance : Growth of Conservation of Volume, in <u>The Essential Piaget</u> Ibid.

Lunzer, E. Problems of Formal Reasoning in Test Situation, In P.H. Mussen (Ed) European Research in Cognitive Development, Monographs of the Society for Research in Child Development, 1946, 1965.

Lunzer, E.A., Harrison, C. and Davey, M. The Four Card Problem and the Generality of Formal Reasoning, Quarterly Journal of Experimental Psychology, 24, 326-339, 1972.

Lunzer E.A. and Pumphrey, P.D. Understanding Proportionality, Mathematics Teaching, 34, 7-13, 1966.

Marek, E.A. Correlations Among Cognitive Development, Intelligence Quotient and Achievement of High School Biology Students, Journal of Research in Science Teaching, Vol.18, No.1, pp. 9-14, 1981.

Martorano, Suzanne C.A. Developmental Analysis of Performance on Piaget's Formal Operations Tasks, Developmental Psychology, 13, 6, 666-72, November, 1977.

Mac Arthur, R.S. Some Differential Abilities of Northern Canadian Nature Youths International Journal of Psychology, 3, 43-51, 1968.

Mathur, S.P. Study of Growth of Experimental mind During Adolescence, M.Ed. Dissertation, University of Rajasthan, Jaipur, Rajasthan, 1981.

Mckinnon, J.W. and Renner J.W. Are Colleges Concerned with Intellectual Development, American Journal of Physics, 39, 1047-1052, 1971.

Mellon, J. Cognitive Development and Processes : Review of the Philosophy of Jean Piaget, American Biology Teaching, 38(1) : 28-23, 1976.

Mclaughlin, G.H. Psychologic : A Possible Alternative to Piaget's Formulation, British Journal of Educational Psychology, 3, 61-67, 1963.

Mealings, R.J. Some Aspects of Problem Solving in Science, M.Ed. Thesis, University of Birmingham, October, 1961.

Menna, U. and Menke, Y. The Development of Formal Thought as Shown by Explanations of the Oscillations of a Pendulum: A Replication Study, Adolescence, 6, 219-228, 1971.

Milton, G. Alexander, Five Studies of the Relation between Sex role Identification and Achievement in Problem Solving, Technical Report 3, Yale University New Haven, Conn, Office of Naval Research, Washington, D.C. 1977.

Misra, A.K. The Role of Hypotheses in Problem Solving, M.Ed. Dissertation University of Rajasthan, Jaipur, 1973.

Modgil, Sohan and Celia, Piagetian Research : Compilation and Commentary Vol. 1 to 8, NFER Publishing Company Ltd., Windsor, Berks, 1976.

Modgil, Sohan and Celia (Eds) Toward a Theory of Psychological Development, NFER Publishing Company Ltd., Windsor, Berks. 1980.

Martorano, S.C. A Developmental Analysis of Performance on Piaget's Formal Operations Tasks, Developmental Psychology, 13, 6, 666, 672, 1977.

Minford, [illegible]. Factors Involved in Problem Solving with Special Reference to the Problem of Insight, Ph.D. Thesis, London, 1937.

Neimark, E.D. A Preliminary Search for Formal Operations Structures, Journal of Genetic Psychology, 116, 223-232, 1970.

Neimark, E.D. Intellectual Development During Adolescence, In F.D. Horowitz (Ed.) Review of Child Development Research (Vol.4), The University of Chicago Press, Chicago, 1975.

Noll, V.H. The Teaching of Science in Elementary and Secondary School, Longmans, London, 1939.

Nordland et al. A Study of Levels of Concrete and Formal Reasoning Ability in Disadvantaged Junior and Senior High School Science Students, Science Education, 58, 4, 569-575, 1974.

Novak, J.D. <u>A Theory of Education</u>, Cornell University Press, Ithaca and London, 1977.

O'Brien T. and Shapiro, B. The Development of Logical Thinking in Children, American Educational Research Journal, 5, 531-541, 1968.

Ogden, William R. and Patricia A. Brewster. An Analysis of Cognitive Style Profiles and Related Science Achievement Among Secondary School Students, Paper Presented at the

Annual Meeting of the National Association for Research in Science Teaching, Cincinnati Ohio, March 22-24, 1977 (ED. 139 610).

Padmini, [illegible] and Vaidya, N. A Factor Analytic View of Adolescent Thought in Piagetian Context, The Educational Trends, Volume 14, No.2, July, 1979.

Pallrand, G.J. The Transition of Formal Thought, Journal of Research in Science Teaching, Vol.16, No.5, 1979.

Pascual-Leon, J.A. Mathematical Model for the Transition Rule in Piaget's Developmental Stages, Acta Psychologica, 32, 301-345, 1970.

Paterson, D.G. et al. *Minnesota Mechanical Ability Tests.* Minnesota University Press Minneapolis, 1930.

Peel, E.A. Psychology and The Teaching of Science, British Journal of Educational Psychology, Nov. 1955.

Peel, E.A. *The Pupils Thinking*, Old Bourne, London, 1960.

Peel, E.A. *The Nature of Adolescent Judgement*, Staples, London, 1971.

Piaget, J. Intellectual Evolution from Adolescence to Adulthood, Journal of Human Development, 15, 1-12.1972.

Piaget, J. *The Grasp of Consciousness* (Action and Concept in the Young Child), Routledge & Kegan Paul, London and Henley, 1976.

Piaget, J. and Inhelder, B. Conservation of Substance, Weight and Volume, In *The Essential Piaget*, Ibid.

Piburn, Michael D. Sex, Field Dependence and Formal Thought, Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Cincinnati, Ohio, March, 22-24, 1977.

Polonski, A. Piaget's Logical Operations and Science Content Comprehension, Diss. Abst. 35, 9,5581-A, 6281 A. 1975.

Quinn, Mary Ellen. Hypothesis Formation can be Taught, The Science Teacher, Vol.39, No.6, Sept., 1972.

Raisada, J. Study of Relationship Between Problem Solving and Some Relative Personality Traits Using Piagetian Type Tasks, M.Ed. Dissertation, University of Rajasthan, Jaipur, Rajasthan, 1981.

Rajput, [illegible] A Study of the Scheme of Proportion Among Certain Group of Adolescent Pupils, Unpublished M.Ed. Thesis, Bhopal University Bhopal, 1975.

Raven, R.J. and Guerin, R. Quasi-Simplex Analysis of Piaget's Operative Structures and Stages, Science Education, 1975.

Renner, J.W. and Stafford, D.G. Teaching Science in the Secondary School, Harper and Row, New York, 1972.

Revlin R. and Mayer, R.E. Human Reasoning, V.H.Winston and Sons, Washington D.C., 1978.

Ross, R.J. Some Empirical Parameters of Formal Thinking, Journal of Youth and Adolescence, 2 (2) 167-177, 1973.

Ross, R.J. The Development of Formal Thinking for High and Average Achieving Adolescence. Paper Presented at the 4th Annual Conference at University Southern California and Los Angeles Children Hosp. 15th Feb., Also Personal Communication, 1974.

Saarni, Carolyn Ingrid. Piagetian Operations and Field Independence as Factor in Children's Problem Solving Performance, Child Development, 44:2; 338-45, June, 1973.

Sandhu, T.S. A Factorial Study of Adolescent Thought Using Piaget Type Tasks, Ph.D. Thesis, University of Rajasthan, Jaipur, Rajasthan, 1980-

Sandhu, T. . and Vaidya, N. Hump Effect as Observed During Problem Solving, Regional College of Education, Ajmer, India, 1978.

Sayer, J. & Ball D. . Piagetian Cognitive Development and Achievement in Science, Journal of Research in Science Teaching, Vol.12, No.2 PP 165-174, 1975.

Sayre, S. and Daniel, W.B. Piagetian Cognitive Development and Achievement in Science Journal of Research in Science Teaching, Vol.12, No.2, pp. 165-174, 1975.

Schwebel, A. Formal Operations in College Freshmen, Journal of Psychology, 91, 133-141, 1975.

Shaycroft, et al. In Experimental Child Psychology, by Hayne, W. Reese and Lewis P. Lipsitt (ed), Academic Press, New York and London, 1970.

Shayer, M. Has Piaget's Construct of Formal Operational Thinking Any Utility? British Journal of Educational Psychology, 49, 265-276, 1979.

Shayer, M. and H. Wylam. The Distribution of Piagetian Stages of Thinking in British Middle and Secondary School Children, II-14-to 16 year Olds and Sex Differentials, British Journal of Educational Psychology, 48, 62-70, 1978.

Siegler, R.S. Liebert, D.E. and Liebert, R.M. Inhelder and Piaget's Pendulum Problem : Teaching Preadolescents to Act as Scientist, Developmental Psychology, 9, 97-101, 1973.

Siegler, R.S. and Liebert, R.M. Acquisition of Formal Scientific Reasoning by 10 and 13 year olds : Redesigning a Factorial Experiment, Developmental Psychology, 11, 401-402, 1975.

Sinclair, H. Recent Piagetian Research in Learning Studies, In M. Schwebel & J.Raph (Eds) Piaget in the Classroom, New York Basic Books, 1973.

Slesnick Irwin. The Effectiveness of a Unified Science, in the High School Curriculum, Ph.D. Thesis, The Ohio State University, U.S.A., 1962.

Somerville, S.C. The Pendulum Problem : Patterns of Performance Defining Developmental Stage, Brit. J. Ed. Psychl.44,3,266-81, 1974.

Sontag and Kagan, J. The Emergence of Intellectual Achievement Motives, American Journal of Orthopschiatry, 33,532-5,1963.

Spearman, C. The Abilities of Man, Macmillan Company, New York, 1927.

Staver, J.R. and Gobel, D.L. The Development and Construct Validation of a Group Administered Test of Formal Thought, Journal of Research in Science Teaching, Vol.16, Issue 6, pp. 535-544, Nov. 1979.

Stephens, W.B. et al. The Development of Reasoning, Moral Judgement and Moral Conduct in Retardates and Normals, Department of Health Education and Welfare, Temple University Philadelphia, Washington, D.C. 1969.

Stephenson, W. Tetrad-Difference for Non-Verbal Subtests, Tetrad-Differences for Verbal Subtests, Tetrad Differences for Verbal Subtests Relative to Non-Verbal Subtests,Journal of Educational Psychology, 22, 167-185, 255-267, 334-3[illegible]4-350, 1931.

Stephenson, W. The Foundations of Psychometry : Four Factor Systems, Psychometrika 1:195-200, 1936.

Stephenson, W. The Study of Behaviour, University of Chicago Press, Chicago, 1953.

Subhadhira, Suphasies, A Correlation Study Between Science Cognitive Achievements of Thai Secondary Students and Their Performances on the Piagetian Task Instrument.

(University of Northern Colorado, 1977). Dissertation Abstracts Internationale, 38 (2) : 716-A, August, 1977.

Suchman, J.R. Inquiry Training in the Elementary School, Science Teacher, 27, 1960.

Thomson, G.H. The Factorial Analysis of Human Ability, Houghton Mifflin Co., New York, 1951.

Thurstone, L.L. Primary Mental Abilities, Psychometric Monograph. 1, 121, 1938.

Thurstone, L.L. The Differential Growth of Mental Ability, 1955.

Tomlinson - Keasy, C. Formal Operations in Females from 11 to 54 years of Age, Dev. Psychology, 6, 364, 1972.

Tomlinson - Keasy, C. Introduction to Formal Operations Task, Unpublished Manuscript, University of Nebraska, 1975.

Tuddenham, R.D. A Piagetian Scale of Cognitive Development in W.B. Dockrell (Ed) On Intelligence. The Toronto Symposium, 1969, London, Methuen, 1970.

Tyler, Sex Differences in Problem Solving by L.J. Sweeney, Stanford University, Stanford, 1953.

Vaidya, N. A Study of Problem Solving in Science Among Certain Group of Adolescent Pupils, M.A. Thesis, Institute of Education, London, 1964.

Vaidya, N. The Growth of Logical Thinking in Science During Adolescence, Oxford & IBH Publishing Company, New Delhi, 1979.

Vaidya, N. The Mathematical Structures Underlying Adolescent Thought, Regional College of Education, Ajmer, Rajasthan, 1981.

Vaidya, N. and Misra, A.M. The Role of Hypotheses in Solving Problems of Science, The Rajasthan Board Journal of Education, 11, 4, 1-10, 1975.

Valentine, C.G. Performance on Two Reasoning Tests in Relation to Intelligence Divergence and Interference Proneness, Br. Jr. of Edml Psych, 45, 198-205, 1975.

Vernon, P.E. *The Structure of Human Abilities*, Methuen and Co., Ltd., London, 1961.

Waite, J.E. A Study Comparing College Science Students Performance on Piagetian Type Tasks, Including Cross Cultural Comparisons, Diss. Absts, March 35, 9, 5581-A, 6201-A, (5954-A), 1975.

Walker, R.A. et al. Written Piagetian Task Instrument : Its Development and Use, Science Education, 63, 2, 211-220, 1979.

Wallace, J.G. *Concept Growth and the Education of the Child*, Slough, England : National Foundation for Educational Research in England and Wales, 1965.

Ward, C.R. A Study of the Development in Fourth and Fifth and Sixth Grade Children of an Understanding of a Particulate Model of Matter, 1975.

Wason, P.C. and Johnson-Laird, P.N. *Psychology of Reasoning : Structure and Content*, Batsford, London, 1972.

Wason, P.C. and Shapiro, D. Natural and Contrived Experience in a Reasoning Problem, Quarterly Journal of Experimental Psychology 23, 69-71, 1971.

Webb, Roger, A. Daurio, Stephen P. Formal Operations in Very Bright 8 to 14 Year Olds, Human Development, 1975.

Wechsler, D. The Measurement and Appraisal of Adult Intelligence. 4th Ed., Williams and Wilkins, London, 1958.

Weeks, [illegible]. The Relationship of Grade, Sex, Socio-Economic Status, Scholastic Aptitude and School Achievement to Formal Operations Attainment in a Group of Junior High School Students, Diss. Abst. International, 34, 5-A, 2405, 1973.

Weitz, L.J., Bynum, T.W., Thomas, J.A., and Steger, J.A. Piaget's System of 16 Binary Operations : An Empirical Investigation, J. Gen. Psych. 123, 279-84, 1973.

Wells, J. Some Aspects of Adolescents Thinking in Science, Ed. Rev. 24, 3, 212-224.

Wheeler D. Studies in the Development of Reasoning In School Children, British Journal of Statistical Psychology, Vol. XI, Part II, pp. 137-159, 1958.

Wollman, W.T. Intellectual Development beyond Elementary School : VI Controlling Variables : A Survey, Unpublished Manuscript, University of California, Berkeley, 1975.

Wonzy, [illegible]. The Effects of Culture and Education on The Acquisition of Formal Operational Thinking, Diss. Abs. Internationals 34, 7, 4015, 1974.

Wonzy [illegible] and Cox [illegible]. The Effects of Task Differences on the Assessment of Formal Operational Thinking, Paper Presented at the Annual Meeting of the American Educational Research Association, Washington D.C., 1975.

Weytright, Loren Dean. Developmental and Methodological Issues in the Growth of Logical Thinking in Adolescence, Dissertation Abstracts, Vol. 33:6, p.2779-A, 1972.

Yudin, L.W. Formal Thought in Adolescence as a Function of Intelligence, Child Development, 37, 697-708, 1966.

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APPENDIX I

QUESTIONNAIRE NO.1

STATING OF HYPOTHESES

Instruction

In this questionnaire, you are given some interesting problems to think. Please read them carefully. These problems tell you what you have to do. It is seen that pupils of your age, solve these problems in many different ways. Your job is to think hard on these problems and suggest as many different answers as you can possibly think of. You should feel free while answering these problems. I may also add that there are no right or wrong answers. I am only interested in knowing about your ability to think.

The work I am doing, has nothing to do with your examination. I am only trying to understand how pupils at your age think to solve these problems. To repeat, your job is to think as freely as you possibly can and write down all the various ideas which come to your mind. It does not matter if they are very strange or different. Sufficient space is provided in this questionnaire itself, for your writing. If you find the space insufficient, please ask for extra sheets. There is no time limit so you can think as long as you wish.

Please number your ideas and write them down neatly. This will help me in understanding your ideas a bit more clearly.

Please raise your hands if you have any question.

Practice Problem

THE DRYING UP OF HANDKERCHIEF PROBLEM

Here is a piece of cloth. Say, it is a handkerchip. It is not dry, that is, it is soaked in some liquid. I want to dry it up as quickly as I can. How can I do it?

Its drying up depends upon certain factors :

1. Length of the handkerchief
2. Material of the handkerchief
3. Moisture in the air
4. Thickness of the handkerchief
5. Nature of the liquid.

These are only the suggestive factors, or they are only the imagined possibilities. You can now think of some more factors which are responsible for the drying up of the handkerchief.

6.
7.
8.
9.
10.

Please continue.

Problem No. 1

THE FLOW OF LIQUID THROUGH A TUBE PROBLEM

Have a look at the diagram given below :

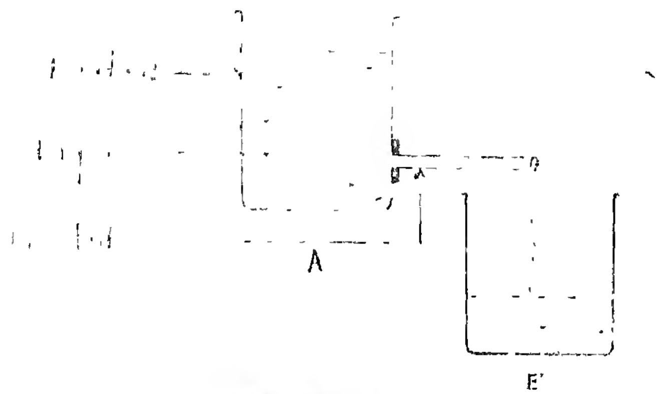


Fig.No.1

There are two beakers A and B. Beaker A contains as much liquid as you wish (want). It (beaker A) is placed at a higher level than the beaker B. A glass tube is fixed to the beaker A. The liquid flows from beaker A through the glass tube into the beaker B. Name all the factors upon which the quick-filling up on the beaker B depends :

1. Size of the beaker A.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Please continue

Problem No. 2

THE SIMPLE PENDULUM PROBLEM

Have a look at the diagram of the Simple Pendulum :

Fig. 2

It consists of a string whose one end is attached to a hook and the other end to a bob. If you give it a slight push, it moves to and fro sideways. To put in other words, it moves from A to B and back to A. This is called ONE OSCILLATION (a complete movement). Now, name all the possible factors on which ONE Oscillation of any Simple Pendulum depends :

1. Colour of the string.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Please continue

Problem No. 3

THE RAMP PROBLEM

Look at the diagram very carefully.

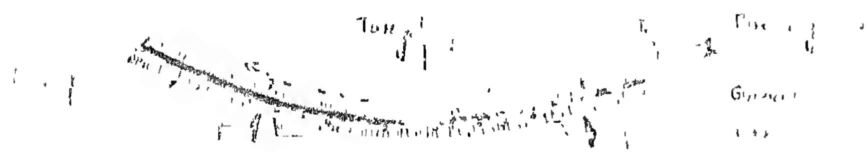


Fig.No.3

There is a ramp with a groove along which spheres can roll up and down. A target sphere is placed at the centre of the ramp. When another (rolling) sphere is released from the right (see the diagram), it rolls down the ramp, strikes the target sphere and makes it move up the ramp on the left.

The movement of the target sphere on any ramp depends on the following possible factors :

1. Height of release of the rolling sphere.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Please continue

Problem No. 4

THE SEED PROBLEM

A farmer wishes to grow healthy plants. Name all the possible factors he should consider to make the seeds grow into healthy plants :

1. Healthy seeds.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Please continue

APPENDIX II

QUESTIONNAIRE No. 2

TESTING OF HYPOTHESES

Instructions

In the earlier questionnaire, you suggested a number of factors that were responsible for the solution of the problem. Now, you are told some factors that might be responsible for the solution of the problem. Your job now is to test these suggested factors in any way you like by designing some experiments. The experiment when performed should clearly tell whether the factor under test is really true or not. To put in other words, it means that your experiment must prove whether the given factor is important or not.

Practice Problem

THE DRYING UP OF HANDKERCHIEF PROBLEM

Example No.1

One student 'A' said that 'Length' of the handkerchief was an important factor in its drying up. When asked to test this factor, he gave the following experiment :

He said, "I shall take three cotton handkerchiefs of different lengths, say of 10 cms 20 cms and 30 cms. In all other respects, they will be exactly the same. I shall dip all the three in water and spread them out in the sun. I will then

note down the time taken for each handkerchief to dry up to the same degree. If the handkerchief of the smallest length (i.e. 10cms) dries up first and that of the largest length (i.e. 30 cms) dries up the last, then I will conclude that 'length' of the handkerchief is an important factor responsible for its drying up. In case, all the three handkerchiefs of different lengths dry up at the same time, then I shall conclude that 'length' is not an important factor."

Example No.2

Another student 'b' said that the material of the handkerchief is an important factor. To test this, he must choose three handkerchiefs similar in all respects the material of the cloth, e.g., cotton, wool and nylon.

He should then dip all the three in water and spread them on the ground. He should then note down the time they take to dry up. If all the three handkerchiefs dry up at the same time, it means that the 'material of the cloth' has no effect in their drying up. If, time taken for each to dry up is different, it means that the 'material' of the handkerchief is an important factor in drying up.

VERY VERY IMPORTANT INSTRUCTION

You are free to change the experimental materials. You are also free to suggest an experiment in any way you like. Anything you need for your experiment is supposed to be available. You have only to write its name.

Remember that you do not have to perform the experiment.

You simply have to describe it in writing. You can also draw diagrams for explaining your point of view. Incidentally, this will also reduce your amount of writing.

You can easily avoid repetitive writing. But, at the same time, try hard to make your ideas as clear as possible for me. This you can safely do by numbering them.

Problem No. 1

THE FLOW OF LIQUID THROUGH A TUBE PROBLEM

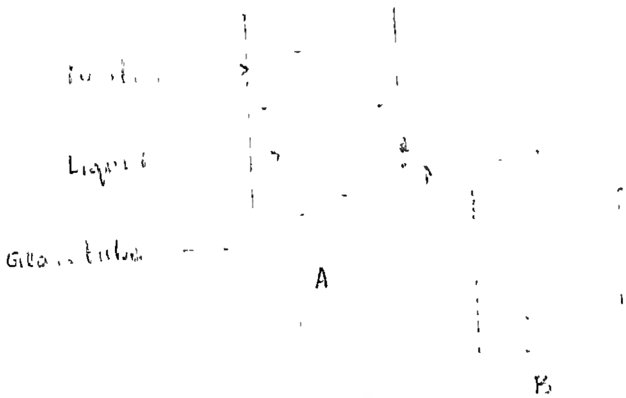


Fig. No.1

Liquid from beaker A flows through a glass tube and collects in the beaker B.

The amount of liquid collected in the beaker B in half an hour, say, depends on the following two factors alone :

1. Size of the hole in the glass tube
2. Level of water in the beaker A.

Suggest experiments to test these two factors :

1. Size of the hole in the glass tube.
2. Level of liquid in beaker A.

Problem No. 2

THE SIMPLE PENDULUM PROBLEM

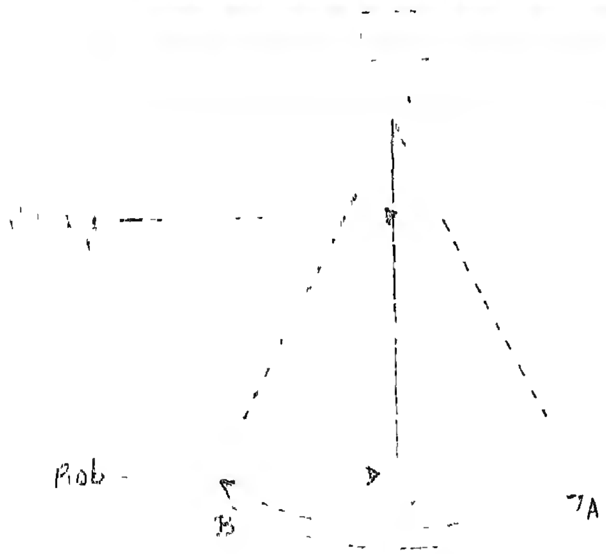


Fig.No.2

The time taken for one oscillation of the pendulum depends upon the following factors :

1. Volume of the bob
2. Weight of the bob.

Suggest experiments to test these factors.

1. Volume of the bob.
2. Weight of the bob.

Problem No. 3

THE RAMP PROBLEM

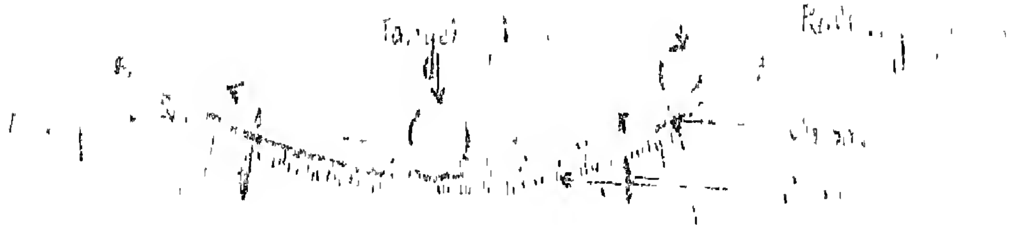


Fig.No. 3

The moving of the target sphere depends on the following factors :

1. The weight of the target sphere.
2. The nature of the surface of the groove.

Suggest experiments to test the above.

1. The Weight of the Target sphere.
2. The Nature of the suface of the Groove.

APPENDIX III

QUESTIONNAIRE No. 3

SOME INTERESTING AND FUNNY QUESTIONS

Instructions

Read the questions very carefully. Some of the questions are very tricky. So, think hard before you answer them. If you want to change your answer, please cross it and then rewrite it.

Problem No. 1

DIGITAL PROBLEM

You are given four digits 6, 7, 8, and 9. Form as many digits or figures as you can by using all these digits in any way you like.

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.

Please continue

21.

Problem No. 2

[illegible]

Frame as many questions as you can on CYCLE whose answers you do not know. In other words, if you know the answer to the question that comes to your mind, please do not write it down. Now start writing those questions only, whose answers you do not know.

Q.1

Problem No. 3

QUESTIONS INVITING WRONG ANSWERS PROBLEM

Q.1. A blind man with one eye can see upto a distance of 100 feet. How far can he see with two eyes?

Ans.

Q.2 A cow is standing beside a tree. A rope or cord of 1 metre is tied around her neck. Tell how far from the tree she can go for eating grass.

Ans.

Q.3 Suppose a donkey has two horns. How many horns in all have eight donkeys?

Ans.

Q.4 A stick is 10 inches long. It is cut an inch per minute. How much time will it take for it to be cut into 1 inch pieces?

Ans.

Q.5 How many corners of the handkerchief are left if you cut off one of its corners with the help of a pair of scissors?

Ans.

Q.6 Suppose some ducks are swimming under a bridge in a single line. Two ducks in front, two in the middle and two behind. How many ducks are there in all? The number of ducks should be as small as possible that is, the smallest.

Ans.

Problem No. 4

THE MAGIC SEEDS PROBLEM

A farmer had some magic seeds. He did not know how to grow them into healthy plants. The only thing he knew was that their growth depended upon the following three factors :

1. Wat~~t~~er
2. Fertilizer
3. Sunlight

HIS PROBLEM was to know the right amount of each of the three factors mentioned above, to be provided to seeds to make them grow into healthy plants. So, he considered giving the above factors at three levels (amounts) as follows :

- Factors
  - Water
    - High
    - Medium
    - Low
  - Fertilizer
    - High
    - Medium
    - Low
  - Sunlight
    - High
    - Medium
    - Low

He then bought several earthen pots with soil in them and sowed a seed in each one of them and designed several experiments to find solution to his problem. Consider his first experiment:

He sowed a seed in the first pot. He put a lot (High amount) of Fertilizer in it. He also gave plenty (High amount) of Water and kept the pot in direct (High) Sunlight.

Your job is to plan as many experiments as you can possibly think of. Please see that no factor or part of the factor is missed by you.

In the table given below, the first experiment is done (entered) for you. Now continue to write the other possible experiments :

Pot No.	Experiment No.	Water	Fertilizer	Sunlight
1.	1	high	High	High
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				

Please continue

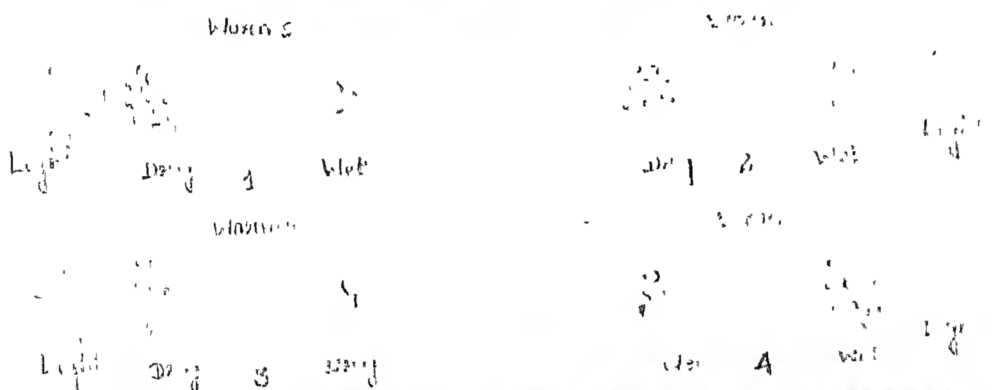
Problem No. 5

THE WORMS PROBLEM

A student of your age wanted to know how Worms move about in Light and Moisture (Wetness).

To solve this problem, he placed 20 worms in the centre of each of the four glass boxes under different conditions of light and moisture. For moisture, water was sprinkled on the bits of paper in the whole box or in half the portion of the box as required. Light was provided by the electric bulb to the required part of the box. His data are shown in the four diagrams given below. Your problem is to have a close look at each of these diagrams and reach a suitable conclusion. You are free to suggest any other experiment, if it might help to solve the problem clearly. It is also possible that the above mentioned student have missed an experiment or two.

Look at the diagrams carefully.



1. What do you concluded from the diagrams (1) and (3)
2. What do you conclude from the diagram (2) and (4)
3. Is any other experiment necessary? If yes, suggest the experiment with diagram.

APPENDIX IV

TABLE OF STUDIES

S. No. 1	Author(s) 2	Year 3	Title of the Study 4	Main Finding(s) 5
1.	Heidbreder, E.	1928	Problem Solving in Children and Adults	Reactions and sensitivity to problems increased from subjective attitude, to a more objective attitude. Whereas the general pattern of the solution become more explicit and definite, new rigidity set in with increasing age.
2.	Russell, R.W. and Dennis W.	1939	Studies in Animism I:A Standardized Procedure for the Investigation of Animism.	All stages were present at all ages included in the investigation.
3.	Bailey, R.G.	1941	The Difficulty level of Certain Science concepts	High mental ability favoured concept development and added allied work as well as activities on the given unit of science.
4.	Kyle	1950	An investigation of the Thought Processes of a Group of 14-year olds During the Solving of a Scientific Problem.	i) Able pupils do not solve problem in stages. In fact, they jump from stages to stage. ii) A problem only becomes real for a person when he has some rudimentary foresight of tentative solution.

1	2	3	4	5
				iii) A 'doing group' went further towards a solution than a thinking group.
5.	Cohen J. and Hansel, C.	1955	The Idea of Independence	Most of the mid adolescent pupils (under 75 per cent) fail to develop the concept of independence.
6.	Buswell	1956	Patterns of Thinking in Solving Problems	i) The subjects experience difficulty in expressing concepts verbally which they had in fact acquired. ii) They do not estimate the answers before they start solving problems. iii) Their failure to distinguish between the relevant and irrelevant aspects of the problem attracts all sorts responses. Variety rather than similarity in the sequence of thinking was the most striking and outstanding characteristics even when common and uniform patterns of thinking during the entire set of problem, solving.
7.	Inhelder B. and Piaget,J.	1958	The Growth of Logical Thinking: From Child Hood to Adolescence	i) Concrete operational subjects can describe the results of their experiments but fail to hold other factors constant. ii) Formal operational subjects attempt to prove something through control experiments.

1	2	3	4	5
				iii) Considering experimentation elsewhere, the hypothesized setting and testing behaviour does not become highly rampant.
8.	Wheeler	1958	Studies in the Development of Reasoning in School Children.	Contradicts Piaget. Elementary schemata are very much there even among young children. It is their subsequent development which describes the difference in performance between the young and the old pupil.
9.	Peel, E.A.	1960	The Pupil's Thinking	Confirms Piaget in principle. Identifies four kinds of thinking, namely, thematic, explanatory, productive and integrative.
10.	Lovell, K.	1961	A Follow-up Study of Inhelder and Piaget's 'The Growth of Logical Thinking'.	Confirms Piaget in principle. The pupil's of low academic ability fail to develop formal operations even past their mid-adolescence.
11.	Mealings	1961	Some Aspects of Problem Solving in Science	i) Problem solving in science is more related to Intelligence than to chronological age. ii) There appears to a minimum mental age of 13 years before a child can reason formally about a problem. iii) Children should not be expected to solve abstract problems below the mental age of 16 plus. iv) There is a time lag between the empirical solution a formal solution.

1	2	3	4	5
12.	Smoke (Ed. Harris & Schevaln)	1961	Selected Readings on Learning Process	i) There is some from of grouping in concept formation. ii) In firm concept formation only, hypotheses are set up and tested for their validity. iii) Insightful behaviour is present in some situations. iv) Subjects have difficulty in expressing their concepts verbally which infact they had acquired.
13.	Beard, R.M.	1962	Children's Reasoning	There are vast individual differences in levels thinking among adolescence pupils studying in different schools. Previous classroom experiences appeared to play an important factor in the separation of variables.
14.	Bruner, J.S. Goodnow, J.J. & Austin, G.A.	1962	A Study of Thinking	Four distinct strategies were distinguished, by which a person may from the given concept: Simultaneous scanning; successive scanning; conservative focusing; focus gambling.
15.	Case, D.D. & Collinson J.M.	1962	The Development of Formal Thinking in Comprehension.	Scores on formal thought varied even when the children were matched on CA and MA but were drawn from different cultural background.

1	2	3	4	5
				ii) Only 58 per cent of them were clear about conservation of volume concept.
17.	Donaldson, M.	1963	A Study of Children's Thinking	
18.	Vaidya, N.	1964	A Study of Problem Solving in Science Among Certain Groups of Adolescent Children.	i) Though adolescent pupils are in a position to state hypotheses most of them are not in a position to test them. ii) They do not contrary to Piaget, exhaust all possibilities. iii) A given problem is solved over a wide i.e. range not only within a given age group but also across the various age groups.
19.	Jackson, S.	1965	The Growth of Logical Thinking in Normal and Sub-Normal Children.	About half of the 15-year-olds do attain the formal operational stage.
20.	Stone, D.R.	1965	Developmental Aspects of Hierarchal Concept Attainment. (Final Report).	i) Scores did not increase with age. ii) Sex difference were not
21.	Lovell, K. & Butterworth, JB	1966	Abilities Underlying the Understanding of Proportionality.	Majority of the adolescent pupils do not reach the formal operational stage.

1	2	3	4	5
22.	Yudin, L.a.	1966	Formal Thought in Adolescence as a Function of Intelligence.	Even adolescent pupils of average intelligence, contrary to piaget, show concrete thinking behaviour as defines by Piaget. Added age is an important factor in the development of formal thought.
23.	Gunnels, F.G.	1967	A Study of the Development in Logical Judgements in Science of Successful and unsuccessful problem solvers in Grades Four Through Nine.	i) Age is an important factor in the development of formal thought. ii) Stage concept in thought or thought develops sequentially is confirmed.
24.	Wellman, J.S.	1969	Methods of Investigating Cognitive Development of Children in Rural Kenya (Some Kamba Results).	Thought becomes more and more complex with age. Their practical ability to sort out for exceeds their ability to verbalize even with very familiar animals.
25.	Dale, L.G.	1970	The Growth of Systematic Thinking : Replication and Analysis of Piaget's First Chemical Experiment.	Very few adolescents perform at the formal operational level.
26.	Karplus R. and Karplus, E.F.	1970	Intellectual Development Beyond Elementary School I: Deductive Logic.	Only 40 per cent of the group of physics teachers used formal operations to solve the Island Problem.

1	2	3	4	5
27.	Bart, W.M.	1971	The Factor Structure of Formal Operations.	In addition to the large general factor, the formal thought did comprise verbal as well as non verbal thought.
28.	Higgins Trenk, A. and Gaite, AJ	1971	Elusiveness of Formal Operational Thought	The American adolescent pupils attain formal thought only 20+ at the age of nineteen or so.
29.	Lee, L.C.	1971	The Concomitant Development of Cognitive and Moral Modes of Thought: A Test of Selected Deductions of Piaget's Theory	About half of the subjects fail to attain formal thought.
30.	Kohlberg and Gilligan, C.	1971	The Adolescent as a Philosopher - The Discovery of the self in a post Conventional World	All normal children attain the concrete operational level during adolescence but most of them do not attain the formal operational level.
31.	Mckinnon, J.W. and Renner, J.W.	1971	Are Colleges Concerned with Intellectual Development.	About three fourths of college freshmen fail to attain formal stage.
32.	Hecke, G. and Hecke, V.	1971	The Development of Formal Thought as shown by Explanations of a Pendulum: A Replication study.	All the fifteen years old adolescent pupils manifested formal thought who systematically approached the simple pendulum problem.

1	2	3	4	5
33.	Dulit	1972	Adolescent Thinking a la Piaget: The Formal Stage	Even two fifths of the gifted pupils (16-17 years) fail to attain formal thought as tested though several Piaget type problems. Even among the general population (20-55 years), about two thirds fail to achieve formal thought.
34.	Hale,J.P.	1972	An Investigation of Two Formal Operational Schemata in Adolescents Enrolled in the ISCS Class Rooms of Three Selected Teachers	A large number of the sample were at the concrete and transitional stage. Students whose scores were low in reading comprehension were not necessarily poor thinkers and those with high scores in reading comprehension were not necessarily good thinkers. Most of the adolescent pupils fail to attain formal thought. Scores reading and thinking do not go together.
35.	Lang,W.A.P.	1972	Difficulty of Some Concepts in Physics.	Even eleven grades fail to manifest formal thinking on problems dealing with mass, weight, properties, speed velocity and acceleration.
36.	Lengel,R.A. & Buell,R.R.	1972	Exclusion of Irrelevant Factors (The Pendulum Problem)	i) between grades 7 to 12, there is gradual growth in the logical operations of exclusion. ii) No sex differences were noticed. iii) Measures of I.Q. and socio-economics status had little relation to conservation.

1	2	3	4	5
37.	Lewis, W.A.	1972	The Influence of Age, Sex and School size upon the development of formal operational thought.	Formal thinking is highly dependent on age rather than any other variable.
38.	Lunzer, E.A. Harrison, C. & Davey, M.	1972	The Four Card Problem and the Generality of Formal Reasoning.	Whereas familiarity with the problem influences performance, the incidence of formal operations is quite low in the general population.
39.	Renner, J.W. & Stafford, D.G.	1972	Teaching Science in the Secondary school.	If formal operations begin at 11+ as hypothesized by Piaget, about one seventh pupils between (10-12 years) appear to possess it.
40.	Wason and Johnson Laird	1972	Psychology of Reasoning: Structure and Content	Very few adults i.e., only the very intelligent among them could solve the four card problem successfully.
41.	Wells, J.	1972	Some Aspects of Adolescent Thinking in Science	Mental age rather than chronological age determines the quality of thinking. However, a wide spread of mean was noticed both for C.A. and M.A. when thinking was classified in various ways: Describe level, Extended describe level, Explainer, Using analogy and Using inference etc.
42.	Weybright, L.D.	1972	Developmental and Methodological Issues in the Growth of Logical Thinking in Adolescence	The Piagetian tasks attracts wider thinking than imagined by Piaget and Inhelder which attempts to fill in the gaps left by them when transition of thought between the concrete and the formal stage is considered.

1	2	3	4	5
43.	Ghatala, J.S.	1973	The Cognitive Operations Specified in the Model	In conceptual learning and development, there are four levels of mastery. The internal conditions of concept learning comprise the level of operation as well as the acquisition of the concept preceding this level.
44.	Griffiths, D.H.	1973	The Study of the Cognitive Development of Science Students in Introductory level courses	Contrary to Piaget, sufficient by less than half attain formal thought which definitely hinders their performance on the experimental equipment despite the fact they had at their disposal the specialised vocabulary.
45.	Misra, R.M.	1973	Role of Hypotheses in Problem Solving Among Grade X Science Students	i) There is no significant differences between top group and bottom group on the number of hypotheses emitted by them. ii) A given problem is solved over a wide I.Q. range i.e. a low I.Q. pupil may solve the problem successfully where as high I.Q. pupil may fail to do so. iii) Many adolescent pupils experience difficulty in testing hypotheses.
46.	Odicxi, K.J.	1973	Affective & cognitive Development: Comparison of Need Achievement and Risk Level with Piagetian Levels of Cognitive Development for two Socio-Economic Groups.	Cognitive development does not very with either n-Ach. or risk level.

1	2	3	4	5
47.	Ross, R.J.	1973	Some Empirical Parameters of Formal Thinking	About half of the undergraduates fail to reach the formal level.
48.	Saarni, C.I.	1973	Piagetian Operations and Field Independence as Factors in Children's Problem Solving Performance	Whereas the field independence did not clarify individual differences meaningfully, the Piagetian developmental level did predict the problem solving performance reasonably well.
49.	Ward, R.W.	1975	A Study of the Development in Fourth, Fifth and Sixth Grade Children of an Understanding of a Particulate Model of Matter	The particulate model of matter is not understood by the tenth graders. Secondly the ethnic background, sex and type of school like variables did not show any significant relationships with performance.
50.	Weeks, R.T.	1975	The Relationship of Grade, Sex, Socio-economic Status Scholastic Apptitude and School Achievement to Formal Operations Attainment in a Group of Junior High School Students.	Ninth grades fail to show formal thinking.
51.	Weitz, L.J. Bynum, T.W. Thomas J.A. & Steger J.A.	1975	Piaget's System of 16 Binary Operations: an Empirical Investigation.	Within the age group (9-16 years) only about one third of the sixteen operations were used which even failed to show development trends.

1	2	3	4	5
52.	Blasi, A. and Hoeffel, E.C.	1974	Adolescence and Formal Operations	The logical foundation for conceptual thought disappears when meanings vary on possibility and reflectivity on analysis.
53.	Case, R.	1974	Learning and Intellectual Development	Even the 7-8 years intelligent and field independent pupils were able to acquire the control of variables in the absence of conservations of weight of combinatorial grouping.
54.	Docherty E.M.	1974	Identifying Concrete and Formal Operational Children	With the help of the Piagetian tasks, it is possible to identify the concrete and the formal stage through cluster analysis.
55.	Graybill, L.W.	1974	A Study of Sex Differences the Transition from Concrete to Formal Thinking Patterns	Sex differences for varying boys in logical thinking were noticed.
56.	Howe, A.	1974	Formal Operational Thought and the High School Science Curriculum.	Barring a few of high mental ability, the rest of the secondary students of higher grades failed to reach the formal operational thought.
57.	Karplus et al	1974	Intellectual Development Beyond Elementary School IV. Ratio: The Influence of Cognitive Style.	About four fifths of the high school students fail to attain the scheme of proportions.
58.	Kidder, F.R.	1974	Investigation of Nine, Eleven and Thirteen year old	Failure to conserve length attracted errors on problems involving Euclidean Transformations.

1	2	3	4	5
			childrens Comprehension of Eluclidean Transformations.	
59.	Lawson	1974	Relationship Concrete and Formal Operational Science Subject matter and the Development level of the Learner	The percentages of students studying chemistry, physics and biology manifesting formal thought are 64, 63 and 35.
60.	Lawson and Renner	1974	A quantitative Analysis of Responses to Piagetian Tasks and Its Implications for Curriculum	About 22 per cent of the college fresh man operate at formal operational level at while 51 per cent and 27 per cent are found at the concrete operational and post-concrete-operational level respectively.
61.	Nordland et al	1974	A Study of Levels of Concrete Ability in Disadvantaged Junior and Senior High School Science Students.	Only about one seventh of the high school
62.	Somerville S.C.	1974	The Pendulum Problem: Patterns of Performance Defining Developmental Stages.	The development of formal thought is strongly dependent on age rather than sex and even the type of school
63.	Wonsy, C.D.	1974	The Effects of Culture and Education on the Acquisition of Formal Operational Thinking.	Formal Thinking (or operations) is seen to be promoted by the sub-urban cultural background.

1	2	3	4	5
64.	Abramowitz S.	1975	Adolescent Understanding of Proportionality Skills Necessary for its Understanding	The nature of the content of the problems definitely the performance of the transitional thinkers between the concrete and the formal stage on the scheme of proportionality.
65.	Arlin,P.K.	1975	Cognitive Development in Adulthood:a Fifth Stage?	About three fifths of the formal thinkers fail to be problem finders.
66.	Bantista,L.B.	1975	The Relationship between Intellectual Levels and Achievement inthe Comprehension of Concepts Classified According to Scheme Derived from Piagetian Model.	The concrete operational students did not differ significants from the formal operational students involving concrete thought only. It is an expected finding.
67.	Bates,G.C.	1975	More on the problem of Physics enrolment	The incidence of formal reasoning increases from biology through chemistry to physics.
68.	Chiapetta E.L.	1975		
69.	Dettrick,	1975	A Study of the Structure of Piagetian Logical and Infra-Logical Grouping within the concrete operational period.	Contrast to Piaget, formal reasoning does not develop at all at 11+. It is usually delayed by about 2-3 years when the cognitive processes really become functional.

1	2	3	4	5
70.	Emmie	1975	Children's ability to Handle Piagets, proportional Logic: Conceptional Critique	Some of the complex operations, contrary to Piaget, are used correctly by the 7-8 years old children. There is also apparently no connection between isolating variables and combinatorial grouping.
71.	Graybill,L.A.	1975	Sex Differences in Problem Solving Ability	Sex differences favouring boys in formal thinking were noticed.
72.	Hathway,W.E.	1975	The Unique Contribution of Piagetian Measurement to Diagnosis, Prognosis and Research of Children's Mental Development.	Piagetian factors do dominately associate themselves with the various measures of school achievement.
73.	Juraschek,W.A.	1975	The Performance of Prospective Teachers on Certain Piagetian Tasks	About half of the elementary school teachers fail to attain formal thought.
74.	Karplus,Karplus, Formisano and Paulsen	1975	A Proportional Reasoning and Control of Variables in Seven Countries.	About three fourths of the pupils definitely fail to develop formal thought on problems relating to proportion and control of variables in seven different countries. The scores on the two problems were not found related to each other over the entire population.

1	2	3	4	5
75.	Keating, D.P.	1975	Precocious Cognitive Development at the Level of Formal Operations.	Majority of the adolescent pupils do not show formal thinking.
76.	Lawson, A.E. & Renner, J.W.	1975	Relationship of Science Subject matter and Developmental levels of Learners	About two thirds of the adolescent pupils do not operate at the formal level which acquiring abstract science fic concepts.
77.	Rajput, M.D.	1975	A Study of the Scheme of Proportion Among Certain Groups of Adolescent Pupils	i) No significant sex differences were noticed on the scheme of proportion. ii) Fluctuations in performance were noticed from lower grades to the higher grades of course with dominating increasing trend with age.
78.	Raven, R.J. and Gurerin, R.	1975	Quasi-simplex Analysis of Piaget's Operative Structure and Stages.	The sequential development supported.
79.	Sayre and Ball	1975	Piagetian Cognitive Development and Achievement in Science	There is a gradual growth of formal thought among science students to complete the Piagetian tasks.
80.	Sayre, S. and Daniel, W.D.	1975	Piagetian Cognitive Development & Achievement in Science.	There is gradual growth of formal thought during adolescence.
81.	Schwebel, M.	1975	Formal Operations in College Freshman.	About four fifths of them do no* show formal thinking on the three Piagetian tasks.

1	2	3	4	5
82.	Valentine, J.R.	1975	Performance on Two Reasoning Tests in Relation to Intelligence, Divergence and Interference Proneness	High Convergent thinking does not guarantee success on reasoning tests.
83.	Waite, J.B.	1975	A Study Comparing College Science Students, Performance on Piagetian Type Tasks, including Cross Cultural Comparisons.	There is no direct bearing of varied cultural backgrounds on the performance of Piaget type tasks.
84.	Wong, C.D. and	1975	The Effects of Task Differences on the Assessment of Formal Operational Thinking.	Age definitely interacted with the number of variables. A problem becomes more different for the adolescent pupils to scheme of more variables are injected into it.
85.	Vaidya, N.	1975	The Growth of Logical Thinking in Science During Adolescence.	i) The complex thinking processes arise from simple thinking processes. ii) Except occasional fluctuations, the mean performance on the various schemes of thought shows on increasing trend with grade. iii) In case this fluctuations is taken seriously, Jump effect is suspected. iv) Where as the adolescent pupils are in a position to set up hypotheses, they are not in a position to test them contrary to Piaget's view.

1	2	3	4	5
86.	Clayton V. and Overton, W.F.	1976	Concrete and Formal Thought Processes in Young Adulthood and old age.	There is variation in formal thought with age.
87.	Cloutiers R. & Goldschimd, M.F.	1976	Individual Differences in the Development of Formal Reasoning	Significant correlations have been obtained between scores on the propor- tion test and non-verbal intellectual capacity as measured by the Raven's [illegible].
88.	Germain, J.G. et al	1976	The Personality of the child and the Utilization of Operative Thought	Significant relationships appeared bet- ween the different measures of opera- tional thinking and different personality variables.
89.	Griffiths, D.H.	1976	Physics Teaching does it hinder intellectual development?	Formal Thinking is necessary to the development of abstract concepts in physics.
90.	Karplus, R. & Arons, A.B.	1976	Implication of Accu- mulating Data on levels of Intellectual Development	About two thirds of the general popula- tion between 13+ to 45+ hardly show formal thought.
91.	Kuhn, D.	1976	Relation of Two Piagetian Stage Transition and I...	The correlation coefficient between mental age and the Piagetian goes on becoming less and less markedly as it tends to become fully formal.
92.	Lawson, A.E. & Blake, A.J.D.	1976	Concrete and formal Thinking Abilities in High School Biology students as measured by Three separate Instru- ments.	About fifty per cent of the high school biology students do not show formal thought.

1	2	3	4	5
93.	Linn & Levine	1976	Adolescent Reasoning: The Development of the Ability to Control variables	i) When the results were stressed and the procedive was hidden from view, the performance of the young adolescents pupils was impaired then the older ones the gap between the being as wide as four years. ii) Both groups of subjects performed similarly on the problems when the results were not shown.
94.	Copper, D.A. et al	1977	The Relation between Formal Operations and a possible Fifth Stage of Cognitive Development.	No relation existed between performance on problem finding and formal operations task.
95.	Joyce, L.K.	1977	A Study of Formal Reasoning in Elementary Education Majors	Subjects show better performance on problems involving syllogisms than on Pendulum problem Testing of hypotheses is little evident among two thirds of them.
96.	Mortorano, S.C.	1977	A Developmental Analysis of Performance on Piaget's Formal Operations Tasks	Mean scores on the ten tasks increase with grade.
97.	Cantu, L.L. & Herron, J.D.	1976	Concrete and Formal Piagetian Stages and Science Concept Attainment	Whereas formal thinking is highly favourable to the development of concrete concepts, both the concrete and formal thinkers to benefit from pseudo examples.

1	2	3	4	5
98.	Grewal, A.	1978	A Study of the Relationship between Hypothesis Testing Ability in Science and Creativity	There is a significant relationship between hypothesis testing ability and the creativity variables like fluency and originality.
99.	Shayer, M. & Wylam, H.	1978	The Distribution of Piagetian Stages of Thinking in British Middle and Secondary School Children 14 to 16 years olds.	There appears to be a stay put in thinking i.e., beyond the age of 15 years, there is no increase in the proportion of pupils showing formal thinking.
100.	Upadhyay	1978	A Study of Intellectual Development and its Relationship with Intelligence and Achievement of 10th Grade Science Pupils	Most of the pupils upto the age of 15 years do not attain formal level.
101.	Pallrand, G.J.	1979	The Transition to Formal Thought	Higher age groups beyond adolescence manifest formal thinking abundantly.
102.	Asnaskar, L.	1979	A Study on the Exclusion of Variables During Adolescence.	i) The mean performance on all the problems shows an increasing trend in stating and testing of hypotheses with grade. ii) All the problems were strongly correlated with each other.

1	2	3	4	5
				iii) Using top 25 per cent and bottom 25 per cent significantly from each other in respect of to the end age grade but not in intelligence.
103.	Walker, A.A. et al	1979	Written Piagetian Task Instrument : Its Development and use	Concrete thinking dominates even at the age of 15 years i.e., little formal thinking is observed.
104.	Sandhu, T.S.	1980	A Factorial Study of Adolescent Thought Using Piaget Type Tasks	i) Performance on Piaget type tasks increases with age. ii) Boys perform either equal or better than girls on the tasks at respective age levels. iii) Significant correlation exists between intelligence and the adolescent thought and between academic achievement and adolescent thought. iv) Personality factors play a significant role in development of adolescent thought.
105.	Mathur, M.	1981	A Study of Growth of Experimental Mind During Adolescence	i) Performance on Piaget type tasks shows an increasing trend with grade with quite a bit of fluctuations on certain tasks. ii) The capacity to grasp the essence of the problem increase with grade.

APPENDIX VI.I

Correlation Matrix (15 x 15)

S.No.	Variables	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
25	w_1P_1(SOH)		628**	564**	524**	177*	245**	169*	215**	020	241**	169*	197**	225**	224**	270**
26	w_1P_2(SOH)			676**	451**	787**	229**	212**	226**	054	262**	229**	186**	246**	050**	304**
27	w_1P_3(SOH)				501**	795**	293**	271**	303**	150*	361**	296**	340**	391**	216**	380**
28	w_1P_4(SOH)					846**	284**	327**	348**	095	389**	213**	373**	376**	350**	374**
29	w_2P_1(TOH)						324**	316**	347**	105	397**	274**	362**	398**	291**	334**
30	w_2P_1(TOH)							534**	453**	022	714**	207**	199**	251**	203**	225**
31	w_2P_2(TOH)								654**	093	852**	231**	177*	234**	000	311**
32	w_2P_3(TOH)									155**	833**	290**	263**	346**	011	408**
33	w_3P_5(TOH)										354**	181**	209**	249**	034	182**
34	TOH (T)											329**	299**	379**	076	407**
35	DP (PAC)												347	710	083	218
36	MSP (PAC)													901	273**	166**
37	PAC (T)														241**	251**
38	F.P															209**

** Significant at 0.01 level

* Significant at 0.05 level

All decimals have been omitted.

APPENDIX IX

ORIGINAL FACTOR MATRIX (h = 15)

S.No.	Variables	Factors 1	2	3	4
25	C_1P_1(SOH)	$\bar{6}27$	503	$\bar{2}30$	046
26	C_1P_2(SOH)	$\bar{6}43$	458	$\bar{2}44$	329
27	C_1P_3(SOH)	$\bar{7}42$	359	$\bar{0}78$	168
28	C_1P_4(SOH)	$\bar{7}31$	292	$\bar{0}69$	211
29	SOH (T)	$\bar{8}46$	468	$\bar{1}61$	$\bar{0}34$
30	C_2P_1 (TOH)	$\bar{5}72$	$\bar{3}69$	$\bar{2}49$	321
31	C_2P_2 (TOH)	$\bar{6}05$	$\bar{5}54$	$\bar{3}27$	$\bar{0}37$
32	C_2P_3 (TOH)	$\bar{6}55$	$\bar{5}19$	$\bar{1}93$	$\bar{0}59$
33	C_3P_5 (TOH)	$\bar{2}59$	$\bar{2}16$	$\bar{2}74$	340
34	TOH (T)	$\bar{7}54$	$\bar{5}96$	$\bar{2}14$	012
35	DP (PAC)	$\bar{5}05$	$\bar{1}48$	485	$\bar{2}65$
36	MDP (PAC)	$\bar{5}68$	$\bar{0}25$	664	106
37	PAC (T)	$\bar{6}59$	$\bar{0}88$	714	$\bar{0}42$
38	FWP	$\bar{3}09$	$\bar{2}52$	226	$\bar{7}63$
39	GRP	$\bar{5}52$	$\bar{0}45$	$\bar{1}03$	$\bar{0}31$
	Pct. of Var.	38.6	14.1	11.5	7.2
	Cum. Pct.	38.6	52.6	64.2	71.3

APPENDIX A

VARIMAX ROTATED FACTOR MATRIX (N = 15)

No.	Variables	Factors 1	2	3	4
25	W_1F_1 (SOH)	824	089	009	120
26	W_1F_2 (SOH)	868	091	089	$\bar{1}51$
27	W_1F_3 (SOH)	788	176	244	036
28	W_1F_4 (SOH)	656	271	156	373
29	SOH (T)	926	212	165	181
30	W_2F_1 (TOH)	143	735	020	261
31	W_2F_2 (TOH)	125	870	079	$\bar{0}53$
32	W_2F_3 (TOH)	163	806	233	$\bar{0}93$
33	W_3F_5 (TOH)	023	139	474	$\bar{2}46$
34	TOH (T)	169	936	253	$\bar{0}31$
35	DF (FAC)	157	159	727	$\bar{0}64$
36	RSF (FAC)	153	095	782	362
37	FAC (T)	189	146	915	239
38	FWF	151	028	075	874
39	GEF	361	393	156	094

APPENDIX II

Original Data Regarding the Different Variables to be Read as Follows

Column number	Description	Short notation used (if any)	Variable No.
1,2,3	Serial number of students	S.No.	
4	Category 1 = Grade VI	-	
	2 = Grade VII	-	
	3 = Grade VIII	-	
	4 = Grade IX	-	
	5 = Grade X	-	
5	Sex : Category 1 = Boys	-	
	Category 2 = Girls	-	
6,7,8	Age in months	AGE	1
9,10,11	Scores on Intelligence	I.Q.	2
12,13	Reserved/Outgoing	A	3
14,15	Concrete thinking/ Abstract thinking	B	4
16,17	Emotionally less-stable/ Emotionally stable	C	5
18,19	Phlegmatic/Excitable	D	6
20,21	Obedient/Assertive	E	7
22,23	Serious/Heedless	F	8
24,25	Expedient/Conscientious	G	9
26,27	Shy/Adventurous	H	10
28,29	Tough-minded/Tender-minded	I	11
30,31	Zestful/Circumspect	J	12
32,33	Secure/Insecure	O	13
34,35	Group Dependent/Self Sufficient	Q_2	14
36,37	Uncontrolled/Self-disciplined	Q_3	15
38,39	Relaxed/Tense	Q_4	16
40,41	Abstract reasoning (DAT)	AR	17
42,43	Numerical ability (DAT)	NA	18
44,45	Mechanical reasoning (DAT)	MR	19
46,47	Space relations (DAT)	SR	20

Column Number	Description	Short notation used (if any)	Variable No.
48,49	Verbal reasoning (DAT)	VR	21
50,51	Spelling (DAT)	Sp	22
52,53	Sentences (DAT)	Sen	23
54,55, 56	Language usage (DAT)	LU	24
57,58	The flow of liquid through a tube problem	W_1P_1(SOH)	25
59,60	The simple pendulum problem	W_1P_2(SOH)	26
61,62	The Ramp problem	W_1P_3(SOH)	27
63,64	The Seed problem	W_1P_4(SOH)	28
65,66	Total score on stating of hypotheses	SOH(T)	29
67,68	The flow of liquid through a tube problem	W_2P_1(TOH)	30
69,70	The simple pendulum problem	W_2P_2(TOH)	31
71.72	The Ramp problem	W_2P_3(TOH)	32
73,74	The Worms problem	W_2P_5(TOH)	33
75,76	Total score on testing of hypotheses	TOH(T)	34
77,78	Digital problem	DP(PAC)	35
79,80	The Magic seeds problem	MSP(PAC)	36
81,82	Total score on permutations and combinations	PAC(T)	37
83,84	Formulating questions problem	FQP	38
85	Grasping the essence of the problem	GEP	39

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1/2	3/4	5/6	7/8	9/10	63/64	65/66	67/68	69/70	71/72	73/74	75/76	77/78	79/80	81/82	83/84	85
16	64	21	65	0[illegible]	10	38	05	04	03	03	15	14	21	35	14	0
16	74	21	58	0[illegible]	00	21	02	06	00	03	11	22	21	43	04	0
16	84	21	53	0[illegible]	15	22	06	06	06	03	21	18	20	38	10	6
16	94	21	56	0[illegible]	09	37	06	06	06	04	22	23	24	47	06	1
17	04	21	56	0[illegible]	10	40	06	06	06	04	22	21	20	41	03	2
17	14	21	66	0[illegible]	05	30	06	06	06	02	20	22	20	42	03	1
17	24	21	57	0[illegible]	12	30	06	06	06	01	19	22	23	45	07	3
17	34	21	57	0[illegible]	15	27	05	04	03	03	15	17	20	37	09	5
17	44	21	56	0[illegible]	13	36	06	06	06	02	20	20	24	44	08	4
17	54	21	65	0[illegible]	12	35	06	06	01	02	15	24	22	46	09	2
17	64	21	60	0[illegible]	12	39	05	05	06	02	18	19	22	41	06	3
17	74	21	64	0[illegible]	11	37	05	04	03	03	15	14	19	33	10	3
17	84	21	64	0[illegible]	10	44	05	05	00	04	14	24	19	43	03	1
17	94	21	56	0[illegible]	10	37	06	06	01	02	15	22	21	43	01	4
18	04	21	56	0[illegible]	12	29	03	06	05	03	14	13	17	30	07	4
18	15	21	74	1[illegible]	14	43	06	06	06	05	23	24	24	48	08	6
18	25	21	73	1[illegible]	15	42	02	06	05	05	18	21	23	44	05	6
18	35	21	78	1[illegible]	20	51	02	06	06	02	16	21	23	44	06	6
18	45	21	68	1[illegible]	27	73	06	06	05	00	17	22	26	48	04	5
18	55	21	76	1[illegible]	16	46	06	06	06	00	18	19	19	38	04	6
18	65	21	75	1[illegible]	30	72	02	06	06	02	16	22	26	48	06	5
18	75	21	72	1[illegible]	12	41	02	02	02	06	12	23	18	41	07	6
18	85	21	68	1[illegible]	23	52	02	06	03	02	13	19	20	39	07	5
18	95	21	74	1[illegible]	16	44	06	02	04	05	17	13	19	42	09	6
19	05	21	69	1[illegible]	09	33	00	06	06	04	14	15	21	36	04	4
19	15	21	78	1[illegible]	10	49	02	06	06	03	17	21	22	43	04	4
19	25	21	68	1[illegible]	24	54	02	02	06	02	12	17	20	37	08	6
19	35	21	68	[illegible]	10	32	02	06	03	06	17	20	22	42	06	4
19	45	21	66	[illegible]	20	44	05	06	06	02	19	17	18	35	05	3
19	55	21	67	[illegible]	13	35	06	06	06	04	22	24	26	50	07	3
19	65	21	75	[illegible]	12	39	03	04	06	03	16	18	26	44	07	6
19	75	21	72	[illegible]	26	59	02	06	06	03	17	18	19	37	07	4
19	85	21	73	[illegible]	27	55	02	01	06	04	13	19	21	40	08	6
19	95	21	71	[illegible]	28	63	06	06	06	02	20	19	21	40	13	4
20	05	21	70	[illegible]	17	43	06	06	06	06	22	24	24	48	07	4